# *EXTERIOR LIGHTING EVALUATION*

***Rowan University – Glassboro Campus***
***Shpeen Hall***
***Glassboro, NJ 08028***

*Submitted To:*

Patrick Gallagher
Department of Planning and Real Estate
Rowan University

*Submitted By:*

Pennoni Associates Inc.
515 Grove St
Haddon Heights, NJ 08035

Robert Mellohusky, PE
MEP Division Manager, Hadden Heights

Proj. No. RCFM1701

December 8, 2017

Table of Contents

## 1. EXECUTIVE SUMMARY

Rowan University has tasked Pennoni to provide a technical analysis of their Glassboro campus exterior lighting system, covering parking lots and pedestrian paths. The task also includes helping the University draft an exterior lighting standard or specification, and to give and prioritize recommendations for future upgrades. Pennoni staff, in two teams of two, were on site primarily during the week of September 18th and September 22nd, 2017. Light readings were taken no sooner than 1 hour after sunset and no later than 1 hour before sunrise.

This week was selected for minimal moonlight contribution, with between 3% and 7% moon illumination (with 0% being a new moon and 100% being a full moon). Moonrise and set times shift from day to day, so that some days of the month, the moon is primarily visible during daylight hours. The moon was only visible as much as 1 hour a night during this week.

## 2. LIGHTING TERMINOLOGIES AND DEFINITIONS

Below is a list of basic lighting terms that will be helpful with the proceeding report. For a more complete list of IES provided definitions, see section 8, **GLOSSERY OF TERMS**.

A. Units of Measurements

1) Lumens – the standard unit of measurement for the brightness of a light source.
2) Footcandles – the standard unit of measurement for the brightness on a target surface.

B. Values for Illumination levels – These key values are commonly listed in a summary of statistics for an area calculated or from field observed readings.

1) Maximum
2) Minimum
3) Average
4) Uniformity Ratios - These ratios are considered more uniform the lower the value. Calculated or field observed ratios are expected to be less than or equal to the stated recommended or required ratio.
    a. Maximum to Minimum (max/min) – a ratio used to define uniformity of most exterior spaces.
    b. Average to Minimum (avg/min) – a ratio used to define uniformity of mostly only roadways.

C. Values related to the Luminaires

1) Lumens – Measure of brightness
2) Wattage – Measure of electrical usage
3) Efficiency – Generally describes how much of the generated light leaves the luminaire
4) Efficacy – A ratio of Lumens per Watt
5) BUG Rating – A newer system of rating the negative spill from a light fixture, replacing the older system of Full Cutoff, Semi-Cutoff and Non-Cutoff. The B relates to Back Light, the U relates to Uplight and the G relates to glare. When presenting this rating, the manufacturer gives each of the three a related number from 0, which is no negative contribution, to 4, which is the highest rating of

negative contribution.

D. Types of Luminaires

1) Shoe Box – Generally a basic, non-decorative, extruded rectangular body roughly of the proportions of a shoe box. This light fixture is commonly used for parking lots. It is often mounted 20ft to 30ft above grade. Most commonly pole mounted with (1) to (4) heads per pole, but can also be building or surface mounted. See Figure 1 below.
2) Cobrahead - Generally a basic, non-decorative, slightly oval shaped head, often with a slightly curved bracket. This light fixture is commonly used for roadways and adjacent sidewalks. It is often mounted 25ft to 3oft above the road surface. Most commonly mounted with (1) head facing the roadway, perpendicular to the curb to a metal pole or wooden utility pole. See Figure 2 below.
3) Decorative Post Top – These light fixtures come in many different styles. They are commonly mounted with (1) head on top of a pole with no arms or brackets, though can be occasionally found twin mounted or more with offset brackets or even overhead brackets for luminaires hanging below the bracket. They can come with shield to prevent or limit upward light, or without. See Figure 9 for the differences.
    a. Acorns – With a glass or polycarbonate lens roughly in the shape of an acorn. This similarity becomes more obvious with the top shield that looks like the cap of an acorn. See Figure 3 below.
    b. Globes – With a glass or polycarbonate lens with a spherical shape.
    c. Indirect – A luminaire with the illuminating element located below a reflecting surface, where light bounces off the reflecting surface and back down. This can lower the luminaire's efficiency and efficacy, but can also reduce glare by reflecting off a diffused surface. See Figure 4 below.
4) Flood light and Spot light – Luminaires with a directed vertical component designed to throw light further forward then the above fixtures. By its nature, they create glare. See Figure 5 below.
5) Wall Packs – A general term for all non-decorative, and some simple decorative, roughly boxed shaped luminaires mounted to a wall or other vertical surface. See Figure 6 below.

**Figure 1 – Shoe Box Luminaire**

**Figure 2 – Cobrahead Luminaire**

**Figure 3 – Acorn Luminaire**

**Figure 4 – Indirect Luminaire**

**Figure 5 – Floodlight**


**Figure 6 – Wall Pack**

E. Types of Illuminance – Different luminaire types can provide a combination of both horizontal and vertical illumination.

1) Horizontal Illuminance – Illumination provided by artificial lighting that illuminates a horizontal surface such as floors, paved surfaces, and table tops. Luminaires that provide primarily horizontal illumination. Different luminaires have reflectors and refracting lenses that created different horizontal distributions. See Figure 9 for IES defined distributions.
2) Vertical Illuminance - Illumination provided by artificial lighting that illuminates a vertical surface such as walls, a person, and building exteriors. See Figure 8 and Figure 8 below for types and effects of different vertical distributions. Better quality lenses and globes can provide vertical illuminance and cut down on the amount of glare. They diffuse or break up the light source(s) to not be as intense directly to the eye (i.e. reduce glare). Lower quality lenses and globes allow the light source(s) being seen directly by the eye, and therefor can cause reduced visual performance or even temporary blindness (i.e. very glary). See Figures 10 – 15 for comparison. This can be dissipated by lower brightness, higher mounting height and/or closer spaced luminaires.

**Figure 8 – Diagram of different types of vertical distribution**

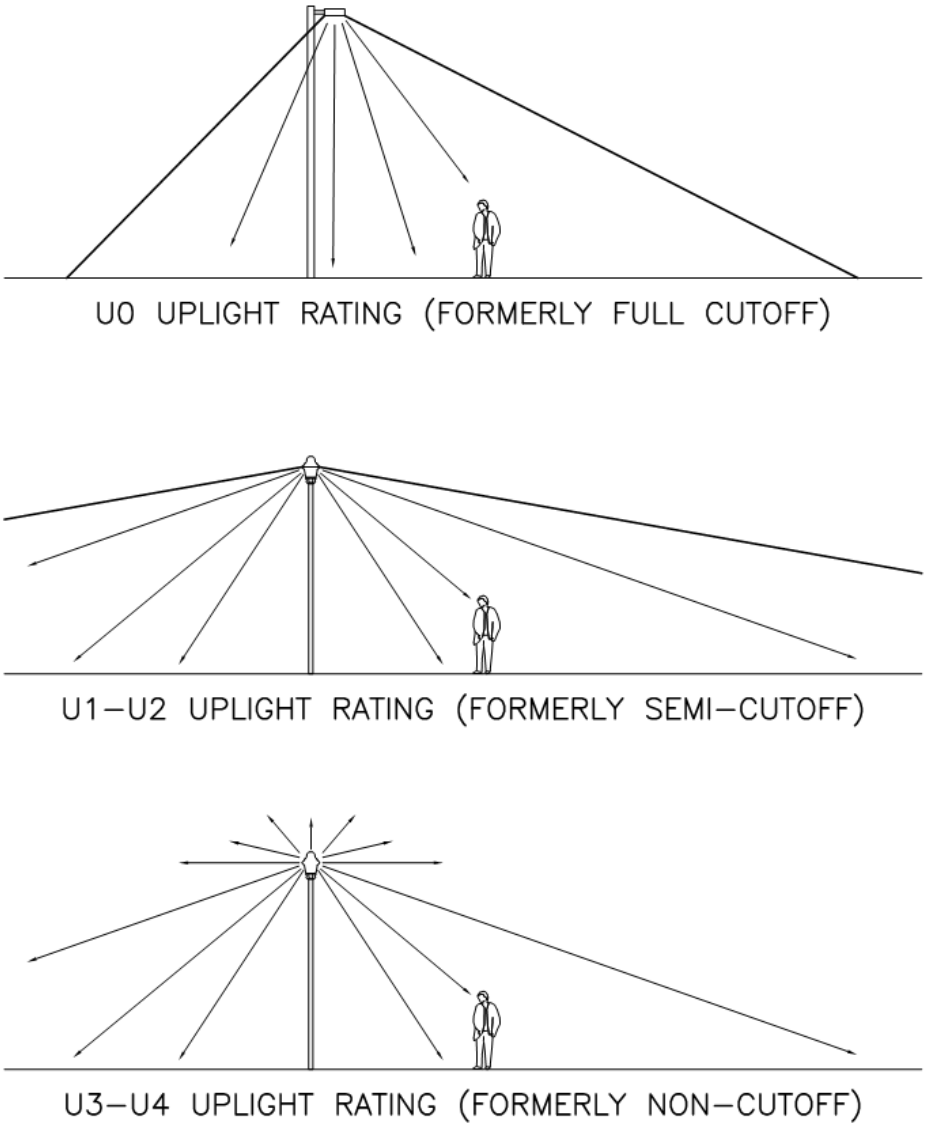
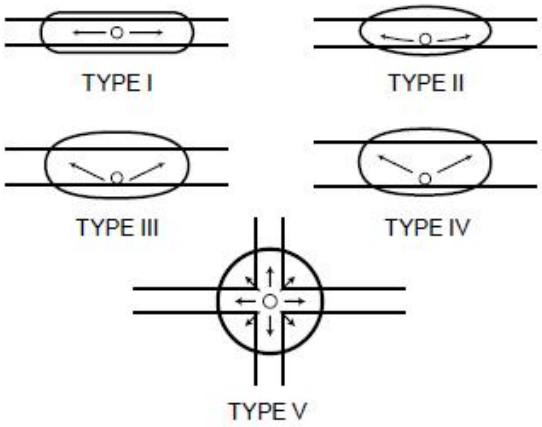



**Figure 9 IES Outdoor lighting distribution types**



F. Glare – As defined by the Lighting Research Center, glare is “a visual sensation caused by excessive and uncontrolled brightness. It can be disabling or simply uncomfortable”. See further delineations below from the Lighting Research Center.

1) Discomfort Glare - “The sensation of annoyance or even pain induced by overly bright sources.” This can be an annoyance, but not necessarily pose a danger.
2) Disability Glare – “The reduction in visibility caused by intense light sources in the field of view”. This can pose a danger for both the safety of a pedestrian, reducing their ability to see and identify, as well as a driver who may momentarily not be able to see.

**Figure 10 – Render of Full Cutoff Decorative Luminaires without Optical Lenses**

**Figure 11 – Render of Semi- or Non-Cutoff Decorative Luminaires without Optical Lenses**


**Figure 12 – Render of Semi- or Non-Cutoff Decorative Luminaires with Optical Lenses**

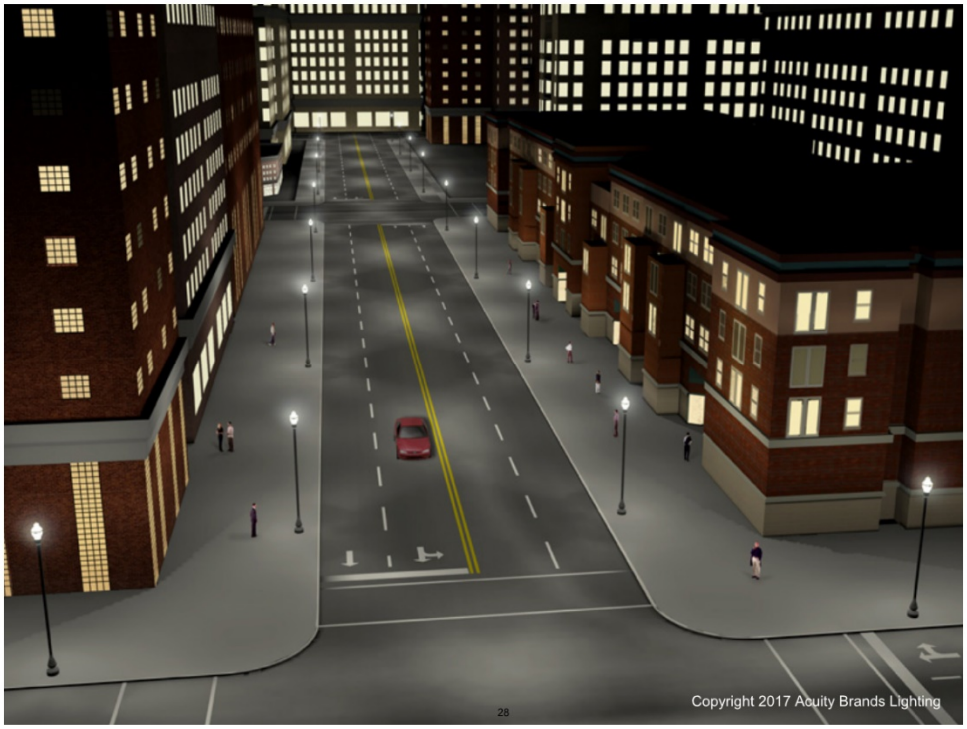


**Figure 13 – Plan of Full Cutoff Decorative Luminaires without Optical Lenses**

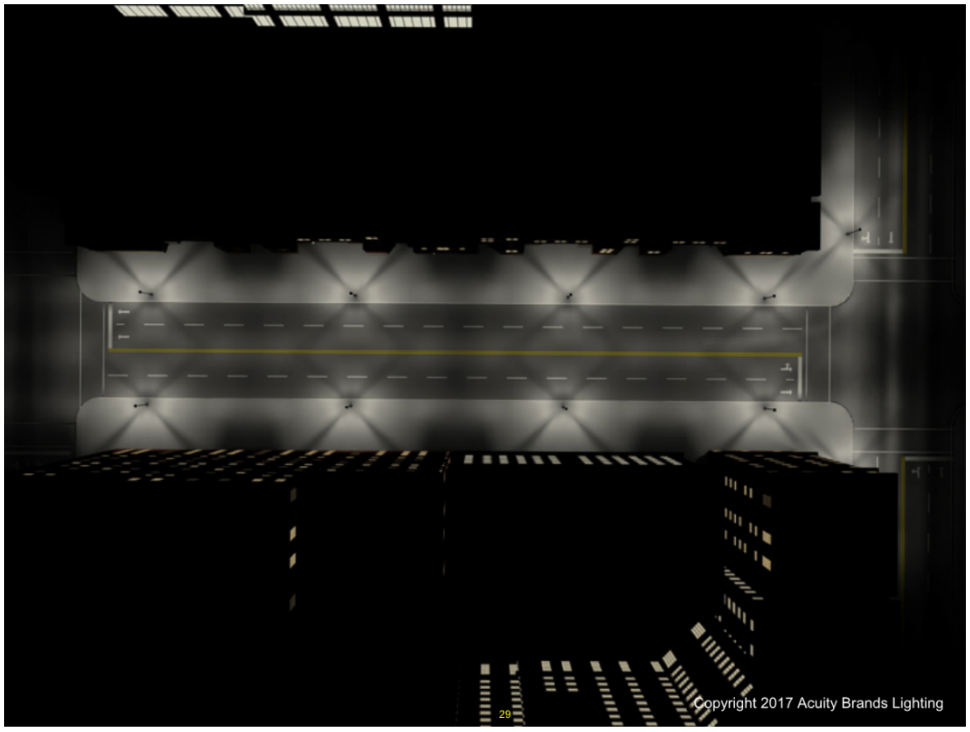



**Figure 14 – Plan of Semi- or Non-Cutoff Decorative Luminaires without Optical Lenses**

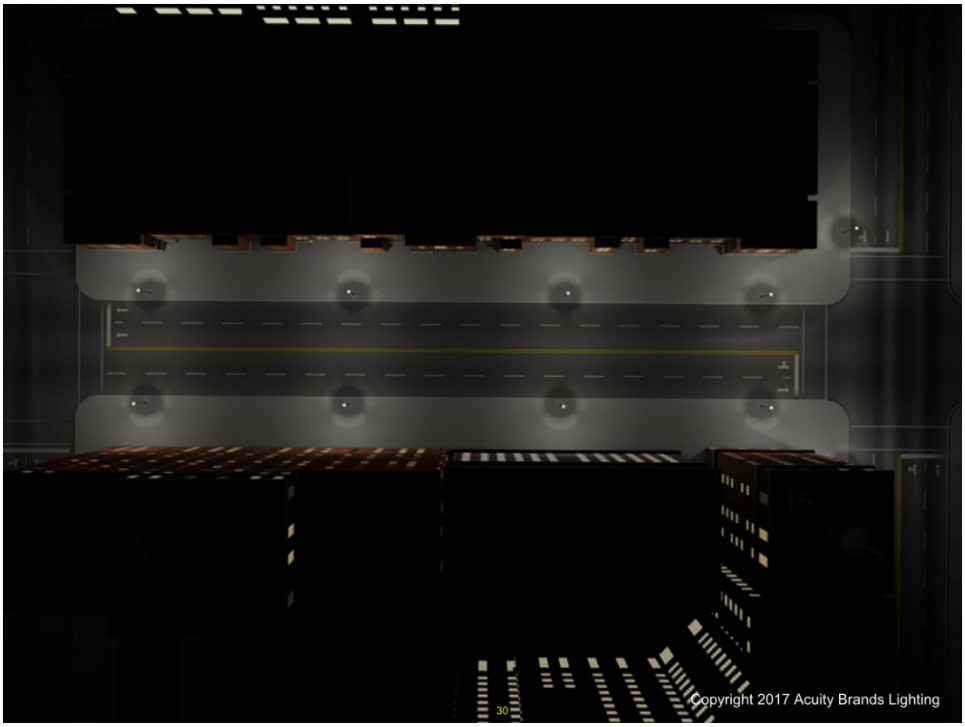
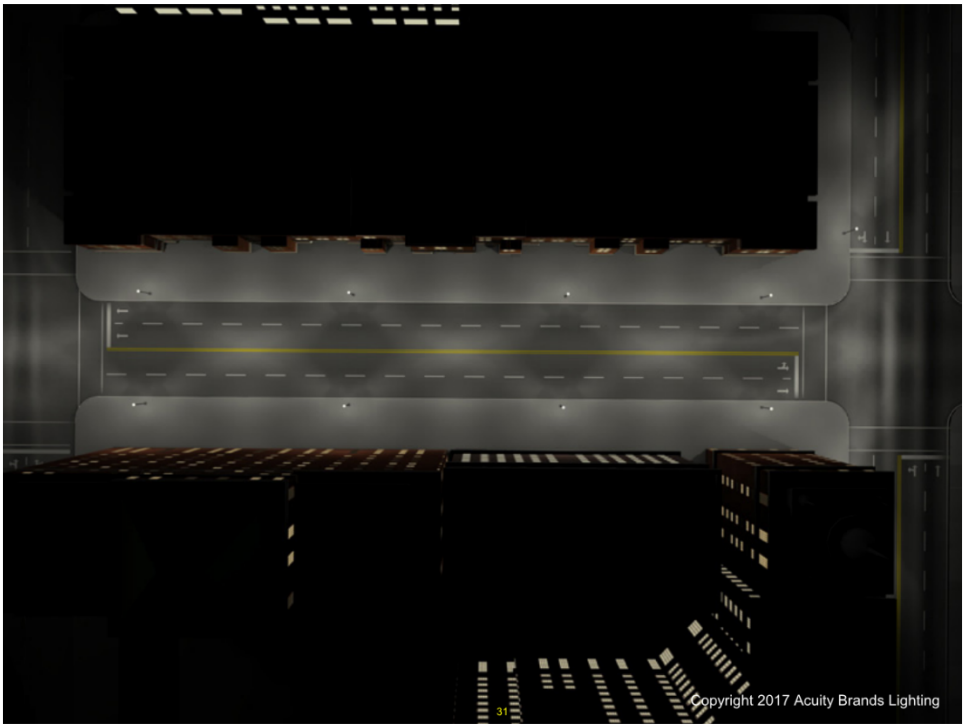


**Figure 15 – Plan of Semi- or Non-Cutoff Decorative Luminaires with Optical Lenses**




## 3. EXISTING CONDITIONS

Rowan University's Glassboro campus is approximately 9,000,000 square feet, or approximately 200 acres, of buildings, parking lots, sports fields, pedestrian spaces and paths. Approximately 3800 points of light readings were recorded across the campus for this report. Light readings were taken at grade, as shown on the plans in Appendices 1 and 2, with the light sensor facing straight up. Typical point spacing was defined as 25ft by 25ft for parking lots and pedestrian areas, and 25ft linearly down the center of pedestrian paths. Care was taken to avoid shadows casted by our staff. We also attempted to avoid taking readings in the shadow of temporary objects, such as parked cars. If that was not possible, any light reading in such a shadow was noted.

The light meters used by our staff were Extech #EA33 and Extech #407026. Distances were measured with a digital distance wheel. AutoCAD backgrounds were provided by the University. Points were plotted out accurately at the predetermined spacing ahead of the site visits in AutoCAD. Point values were tabulated in excel based on different zones established by designating each parking lot as its own zone, and breaking up pathways into groups between buildings.

See Campus Key Plan – Area Designations in Appendix 1 for zone names and delineations. Areas in Table 1 are alphabetical, parking lots first, then area paths, then sidewalks. Areas described in sections 3.A. and 3.B. are ordered according to the LETTER/NUMBER coordinate system on all drawings in the appendices, first going across the letters, then going down to the next number and across the next row of letters. The following observations from the field without bias or comments for improvements. Refer to section 6 for recommendations.

**Table 1 – Summery of Existing Illumination Levels Recorded**

| Area | Average | Max | Min | Max/Min | Avg/Min | Percent 0.0 |
|---|---|---|---|---|---|---|
| Chestnut Lot | 0.4 | 2.2 | 0.0 | N/A | N/A | 25.6% |
| Edgewood Lot | 0.6 | 3.6 | 0.0 | N/A | N/A | 5.7% |
| Lot A | 0.3 | 3.8 | 0.0 | N/A | N/A | 56.2% |
| Lot B | 2.6 | 13.0 | 0.3 | 43.3:1 | 8.6:1 | 0.0% |
| Lot C | 1.8 | 11.7 | 0.3 | 39.0:1 | 6.0:1 | 0.0% |
| Lot D | 0.8 | 12.3 | 0.0 | N/A | N/A | 7.3% |
| Lot D1 & D2 | 1.2 | 7.1 | 0.2 | 35.5:1 | 5.9:1 | 0.0% |
| Lot E | 0.5 | 2.1 | 0.1 | 21.0:1 | 5.3:1 | 0.0% |
| Lot F | 0.8 | 9.5 | 0.0 | N/A | N/A | 20.5% |
| Lot G | 1.4 | 6.1 | 0.1 | 61.0:1 | 14.0:1 | 0.0% |
| Lot H | 1.2 | 3.4 | 0.2 | 17.0:1 | 6.0:1 | 0.0% |
| Lot J | 4.8 | 12.5 | 1.6 | 7.8:1 | 3.0:1 | 0.0% |
| Lot K | 1.2 | 3.7 | 0.1 | 37.0:1 | 12.1:1 | 0.0% |
| Lot M | 1.6 | 3.0 | 0.2 | 15.0:1 | 7.8:1 | 0.0% |
| Lot O | 0.5 | 6.0 | 0.0 | N/A | N/A | 7.8% |
| Lot P | 1.1 | 2.7 | 0.0 | N/A | N/A | 3.2% |
| Lot R | 1.5 | 2.9 | 0.5 | 5.8:1 | 3.1:1 | 0.0% |
| Lot T | 1.5 | 2.0 | 0.8 | 2.5:1 | 1.9:1 | 0.0% |
| Lot U | 3.4 | 6.1 | 0.7 | 8.7:1 | 4.8:1 | 0.0% |
| Lot W | 2.1 | 9.6 | 0.0 | N/A | N/A | 4.3% |
| Lot X | 3.4 | 5.2 | 1.9 | 2.7:1 | 1.8:1 | 0.0% |
| Lot Y | 1.1 | 3.7 | 0.1 | 37.0:1 | 10.7:1 | 0.0% |
| Lot Z-1 | 0.2 | 0.8 | 0.0 | N/A | N/A | 4.5% |
| | | | | | | |
| Baseball Area Paths | 1.6 | 9.8 | 0.0 | N/A | N/A | 25.6% |
| Bunce Hall Area Paths | 0.8 | 9.9 | 0.0 | N/A | N/A | 10.7% |
| EPA Area Paths | 1.3 | 16.4 | 0.0 | N/A | N/A | 3.4% |
| Evergreen Hall Area Paths | 0.9 | 4.5 | 0.0 | N/A | N/A | 2.2% |
| Football Area Paths | 1.4 | 6.5 | 0.0 | N/A | N/A | 28.3% |
| Hawthorn Hall Court Yard | 1.1 | 3.1 | 0.2 | 15.5:1 | 5.3:1 | 0.0% |
| Holly Point Area Paths | 2.2 | 21.1 | 0.0 | N/A | N/A | 1.6% |
| Laurel Hall Area Paths | 0.6 | 4.3 | 0.0 | N/A | N/A | 8.9% |
| Meditation Walk | 1.1 | 3.8 | 0.0 | N/A | N/A | 2.4% |
| Robinson Hall Area Paths | 1.1 | 36.0 | 0.0 | N/A | N/A | 17.6% |
| Rowan Hall Area Paths | 1.4 | 8.2 | 0.0 | N/A | N/A | 9.6% |
| Science Hall Area Paths | 1.8 | 16.3 | 0.0 | N/A | N/A | 7.8% |
| Student Center Area Paths | 1.4 | 2.8 | 0.2 | 14.0:1 | 6.9:1 | 0.0% |
| Student Center Court Yard | 1.2 | 11.6 | 0.0 | N/A | N/A | 8.9% |
| Townhouse Paths | 1.0 | 4.0 | 0.0 | N/A | N/A | 1.2% |
| | | | | | | |
| Holly P to Chestnut Sidewalk | 2.4 | 14.5 | 0.0 | N/A | N/A | 16.1% |
| RT 322 Sidewalk | 1.6 | 7.1 | 0.2 | 35.5:1 | 7.9:1 | 0.0% |

A. Parking Lots

1) Lot D – Sheets 1A and 2A
This lot is primarily lit from one side with pole mounted flood lights on the north-west side, adjacent to Bowe Blvd. Some of these luminaires are blocked by trees. The half of the parking lot closer to the roadway has fair illumination levels, but the further half has little to no light. This can cause safely issue, as the dark area is between the stadium and the better lit half of the parking lot.

2) Lot C – Sheets 2A
This lot is primarily lit from one side with pole mounted flood lights on the north-east side, adjacent to Carpenter St. The half of the parking lot closer to the roadway has good illumination levels closer to the poles, but the further half drops off to a lower level. The lower half would be considered very dark, and the transition from one side with light poles to the other is even. Flood lighting is not ideal for parking lot lighting, as the glare from aimed lighting can be an issue, though it is not excessive in this case. The luminaires are a combination of metal halide and high pressure sodium, giving an inconsistent color temperature and color rendering.

3) Lot O – Sheets 1B and 2B
This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot, both in curbed islands, and at intersection of parking spot striping. This lot has a large percentage of low light readings, including a fair number of 0.0 and 0.1 fc readings. The illumination levels would be described as generally under-lit, with most of the higher light readings very close to the light poles at James Hall. However, there is no illumination contribution from these luminaires to the park area across the street. This area is in complete darkness.

4) Lot B – Sheets 1B and 1C
This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot, both in curbed islands, and at intersection of parking spot striping. This lot is well lit with an average that is more than double the industry standard and with an acceptable minimum. The max/min is much higher than industry standards, but that is because of a higher than normal maximum, not a lower than accepted minimum.

5) Edgewood Lot – Sheets 1C and 1D
This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot, in curbed islands. There was one light out on the night light readings were taken. There was also a lot of shadowing due to trees in this lot. The illumination levels would be described as generally under-lit, with very few higher light readings. The illumination level appears to be due to a combination of poor illumination and shadowing from trees.

6) Chestnut Lot – Sheet 1D
This lot is lit from typical pole mounted shoe box luminaires, located on the street side edge of the parking lot. The illumination levels would be described as very under-lit, with no higher light readings. The illumination level appears to be due to a combination of poor illumination and shadowing from trees.

7) Lot X – Sheets 1E and 1F
   This lot adjacent to Holly Point Commons appears to be lit recently added LED luminaires. The lighting levels are very bright, about 3 times industry standards and very uniform. The lighting levels would be described as very well lit. With its visibility and accessibility from 3 adjacent roads, this is warranted.

8) Lot D1 & D2 – Sheet 1A
   This lot is lit from a mix of typical pole mounted shoe box luminaires and post top decorative luminaires, located within the parking lot. This lot is moderately lit with an average matching the industry standard and with an acceptable minimum. The max/min is much higher than industry standards, but that is because of a higher than normal maximum, not a lower than accepted minimum.

9) Lot M – Sheets 2B and 2C
   This lot is lit from a mix of typical pole mounted shoe box luminaires and pole mounted flood lights, located on the perimeter of the parking lot. This lot is moderately lit with an average about 1.5 times industry standard and with an acceptable minimum. The max/min is within industry standards for enhanced security. Due to the use of flood lights, the lighting does appear glary, but not excessively so.

10) Lot W – Sheet 2C
    This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot. This lot is well lit with an average that is more than double the industry standard and with one section primarily 0.1 to 0.0 foot candles.

11) Student Center Loading Dock – Sheets 2D and 3D
    This area at and around the loading dock had no illumination. The area was in complete darkness.

12) Lot K – Sheets 2D and 2E
    This maintenance yard/parking lot is lit primarily by pole mounted flood lights and building mounted luminaires. Except for one corner of the lot, this lot is moderately lit with an average matching the industry standard and with an acceptable minimum. The max/min is much higher than industry standards, due to a lower than accepted minimum. Due to the use of flood lights, the lighting does appear glary, but not excessively so.

13) Lot U – Sheets 2D and 3D
    This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot. The lighting levels for this lot appears to be very bright, about 3 times industry standards and very uniform. The lighting levels would be described as very well lit. With its visibility and accessibility from Rt. 322, this is warranted.

14) Lot J – Sheets 2D, 2E and 3D
    This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot. The lighting levels for this lot appears to be very bright, approaching excessively so, about 5 times industry standards and very uniform. The lighting levels would be described as very well lit. With its visibility and accessibility from Rt. 322, this is warranted, though a bit more than necessary for even that location and considering increased University standards.

15) Lot T – Sheets 3E

This small lot is lit from typical pole mounted shoe box luminaires. This lot is moderately lit with an average about 1.5 times industry standard and with an acceptable minimum. The max/min is well within industry standards for enhanced security.

16) Lot F – Sheets 4A and 4B

This lot is lit from typical pole mounted shoe box luminaires at the perimeter and cobraheads within the striping. This lot has large percentage of low light readings, including a fair number of 0.0 and 0.1 fc readings. The illumination levels would be described as generally under-lit, with most of the higher light readings very close to the light poles.

17) Lot A – Sheets 4A and 5A

This lot is lit from a combination of cobraheads and decorative post tops from the edges and typical shoe box luminaires within. Though this lot appears to be recently constructed, light levels appear to be under-lit, with a large number of low readings, including a lot of 0.0 fc readings. There did not appear to be any luminaires out at the time. It did appear that the low levels were more due to tree shading of the perimeter luminaires and too far apart spacing of luminaires within the parking lot, leaving many dark spots between poles.

18) Lot G – Sheets 4C

This small lot is lit from a combination of typical shoe box luminaires and post top decorative luminaires. Though the average illumination level appears to be slightly higher than industry standards, this number is skewed due to a small amount of readings, some high, but most very low. This lot would generally be considered under-lit, and being that the lot is tucked off in location, could be considered a greater security issue.

19) Lot Z-1 – Sheets 4C and 5C

This lot is lit from typical pole mounted shoe box luminaires, located within the parking lot. This lot has large percentage of low light readings, including a fair number of 0.0 and 0.1 fc readings. The illumination levels would be described as generally under-lit, with no higher light readings.

20) Lot H – Sheets 3C, 4C and 4D

This lot is lit from typical pole mounted shoe box luminaires located within the parking lot. This lot is moderately lit with an average matching the industry standard and with an acceptable minimum. The max/min matches industry standards for a normal parking lot, but not for enhanced security. There is one small section to the south that has almost no illumination.

21) Lot P – Sheets 4D and 5D

This lot is lit with LED luminaires that appear to be recently installed. Except for the entrance to the lot and around the Carriage House, where there is little to no illumination, this lot is moderately lit with an average slightly above industry standards, and is even and uniform.

22) Lot R – Sheet 5D

This lot is lit with LED luminaires that appear to be recently installed. This lot is

moderately lit with an average about 1.5 times industry standards, and with an uniformity exceeding that required for enhanced security.

23) Lot Y – Sheet 6C
This lot is lit from a mix of metal halide and high pressure sodium shoe box luminaires on the southern end and decorative post top luminaires on the northern end. There was some shadowing by trees on the south side of the parking lot. Part of the southern end of the parking lot is well lit, with the remainder generally under-lit.

B. Pathways – All pathways were lit with post top decorative luminaires except where noted.

1) Football Area Paths – Sheets 1A and 2A
This area's paths have a slightly higher average than industry standards, but with some whole sections of little to no illumination.
   a. Northern Paths - Very little illumination for this section.
   b. Paths around Green Team House – Except for one spot on western side, acceptable illumination levels.
   c. Path leading to Lot O - No Illumination at this path.

2) Baseball Area Paths – Sheets 1B, 1C, 2B and 2C
This area's paths have a slightly higher average than industry standards, but with some sections of little illumination.
   a. Paths south of Lot B – Greater than industry standard.
   b. Path adjacent to Baseball field – Except for a bright spot adjacent to a luminaire, very little illumination.
   c. Paths leading off Lot O – Almost no illumination.
   d. Paths around James Hall – Though not to University standards, approximately matching industry standards.

3) EPA Area Paths – Sheets 1C, 1D, 1E, 2C and 2D
This area's paths have a slightly higher average than industry standards, but with a number of sections of low illumination.
   a. Paths around EPA 200, EPA 400, EPA 500 and EPA 800 – besides the paths between EPA 300 and Magnolia Hall, which meet industry standards, the remainder of the paths are lower than industry standard lighting levels
   b. Courtyard within Chestnut Hall – besides a few higher illumination readings, this section has very little illumination.
   c. Courtyard within Magnolia Hall – This area has slightly less than industry standards for illumination.
   d. Courtyard within Willow Hall - This area has slightly more than industry standards for illumination.
   e. Path south of (3) Halls - This path has slightly more than industry standards for illumination.
   f. Sidewalks adjacent to Parking Lots - besides a few higher illumination readings, this section has very little illumination.
   g. Paths North of Cassidy Building – The path leading from Willow Hall has very little illumination, but the path north of Cassidy Building is very well lit.

4) Holly Point Area Paths – Sheets 1D, 1E, 1F, 2D and 2E

Paths in this area are well lit, approximately 2 times industry standards, except for the following.

a. Path south of Holly Point Commons – Approximately industry standards with a small section of lower light levels.
b. Path from Cassidy Building to Rt. 322 (Cassidy Lane) – Except for a small section in front of a small building along path, remainder of path very low illumination.
c. Path adjacent to Rt. 322 – Path has slightly less than industry standard with about a quarter of the readings almost without illumination.

5) Rowan Hall Area Paths – Sheets 2A, 2B, 3A, 3B, 4A and 4B
   a. Paths around Rowan Hall – Paths immediately adjacent to the hall are well lit. There is a small pedestrian area with very little illumination at the rear of the Hall, leading into a small pond. There is also no railing or obstacle for entering the water, leaving a very unsafe situation at night.
   b. Paths west of Rowan Hall – Paths general lit slightly less than industry standards, with a few completely dark spots.
   c. Paths south of Rowan Hall (throw woods) – Path is illuminated with pole mounted shoe box luminaires. Path alternates with bright spots at luminaire locations and sections of little to no light between poles.

6) Robinson Area Paths – Sheets 2B, 2C, 3B and 3C
   a. Courtyard within Wilson Hall – This section was lit from building mounted luminaires only. Section was generally under-lit, with the northern side close to the building completely dark.
   b. Paths around of Wilson Hall – Paths to the north and south were adequately lit, but paths to the east and west had little to no illumination.
   c. Paths North of Robinson Hall – This section was only illuminated by luminaires from the building roof. There were also a lot of shadowing, further reducing illumination levels. Most of this section had little to no illumination.
   d. Paths around Robinson Hall – Except for north of the building, these paths had little illumination.
   e. Paths around Rec Center – The north, east and south-east paths of this section were adequately lit. Paths to the south, south-west and north east were under-lit.
   f. Paths around Mimosa Hall – Paths leading to the Student Center Courtyard to the south-west of the Hall are under-lit. The remainder of this section is well lit. There were some issues with lack of clarity and facial recognition due to poor vertical illumination contrast (silhouetting) while crossing the bridge directly to the Student Center Courtyard.

7) Meditation Walk – Sheets 3B, 3C and 4B
   The path was recently constructed. The eastern most section of this path was not complete at the time of field observations, and luminaires were not energized. The remainder of the path was well illuminated.

8) Science Hall Area Paths – Sheets 3B, 3C, 4B and 4C
   a) Paths around Rohrer Building – Paths are well lit to at least 2 times industry standards.
   b) Paths around Westby Hall - Paths are well lit to at least 2 times industry standards.
   c) Paths around Science Hall – Except for small courtyard north of the Hall, which is slightly under-lit, paths are well lit to at least 2 times industry standards.
   d) Paths around Savitz Hall (Admissions) - Except for paths north of the Hall, which is

about industry standards, paths are well lit to at least 2 times industry standards.

9) Student Center Courtyard – Sheet 3C
   The courtyard is mostly illuminated with building mounted flood lights. They are slightly glary counting on what view point you are at. The southern corner of the courtyard is well lit, but the majority of the remainder is had little to no illumination, leaving a poor uniformity and poor safely conditions.

10) Evergreen Hall Area Paths – Sheets 3D, 3E and 4D
    a. East of Evergreen Hall – Paths are generally well lit approximately 2 times industry standards.
    b. West of Evergreen Hall – Paths are generally moderately lit approximately at industry standards.
    c. North of Linden Hall – Except for a few bright spots, paths are generally under-lit.
    d. South of Linen Hall – Paths are generally poorly lit with mostly dark areas.
    e. South of Laurel and Oak Halls - Paths are generally moderately lit slightly less than industry standards.

11) Townhouse Paths – Sheets 4B, 4C, 5B and 5C
    Except for a few paths, this area is generally well lit, with illumination at or above 2 times industry standards.

12) Hawthorn Hall Courtyard – Sheet 4C
    Though this area only has an average of just above industry standards, it is very consistent and uniform, with a safe feel to the illumination.

13) Laurel Hall Area Paths – Sheet 4D
    Though this area only has an overall average of below industry standards, with some under-lit paths at the edges, the paths at the heart of this area it is very consistent and uniform, with a safe feel to the illumination.

14) Bunce Hall Area Paths – Sheets 4C, 4D, 5C, 5D, 6C and 6D
    a. Paths around Bozorth Hall - Paths are generally moderately lit approximately at or slightly less than industry standards. Paths south of the building are isolated and only lit from building mounted luminaires, which do not give a safe feel and a lack of clarity and facial recognition due to poor vertical illumination contrast at different spots.
    b. Paths east of Bunce Hall – Section immediately adjacent to the Hall are generally well lit approximately 2 times industry standards.
    c. Paths west of Bunce Hall - Paths are generally under-lit, with path to baseball field bleachers very under-lit.
    d. Paths around Memorial Hall – Paths south and west of the Hall are generally under-lit. Remainder of paths in this section are very under-lit. With this section with many pockets between odd shaped buildings, this leaves unsafe conditions.
    e. Paths around Bole Hall and Annex (Police Building) – Except for path along west side of Bole Hall, which is well lit, the paths in this section are under-lit to poorly lit.

C. Sidewalks

1) Rt. 322 (Mullica Hill Road)
   The sidewalks along Rt. 322 are primarily illuminated by utility mounted cobra heads,

mostly twin head, with one facing street side, and one sidewalk side. There were also spots where decorative post top luminaires were found as well, generally where paths began, moving away from the roadway. The sidewalks in this area are generally about 2 times industry standards, with some sections that drop to approximately industry standards.

2) Carpenter Street
The sidewalk between Holly Point Commons and Chestnut Hall are well lit at least 2 times industry standards up until the last section approaching Chestnut Hill. There was one light out in this section, but there appeared to be a larger section of dark light readings than one light could have illuminated.

## 4. INDUSTRY STANDARDS

A. Institutions and Documents

There are no national codes or requirements for illumination levels in the US, except for paths of egress within a building, and light immediately outside of all exterior exits of a building. This is considered emergency lighting. Many municipalities have their own lighting ordinances, though often very basic. Industry standards for lighting primarily come from the Illuminating Engineering Society of North America (IESNA or just IES). There are some specialty subsets of lighting design such as roadway and parking structure lighting from other institutions. Though these do not apply to the areas of evaluation for this report, they are applicable to the writing of the University lighting standard.

For roadway lighting recommendations, as well as the IES, the American Association of State Highway and Transportation Officials (AASHTO) has the document GL-6, Roadway Lighting Design Guide. Many state DOT's require the following of this document for state funded roads. For parking structure lighting recommendations.

B. Illumination Levels

The tabled below are from illumination levels listed in the IES RP-33-14, Recommended Practice (RP), Lighting for Exterior Environments. Values were taken from charts in that RP based on the campus being the lighting zone LZ-2, which is recommended by the IES for light commercial districts and high density or mixed use residential districts.

1) Building Entries

**Table 2 – IES Recommended Illumination Levels for Building Entries**

| Type | Horiz Avg | Vert Avg | Avg/Min |
|---|---|---|---|
| **Canopied Entries/Exit** | | | |
| High Activity | 2.0 | 1.0 | 2.0:1 |
| Mid-Low Activity | 1.0 | 0.6 | 2.0:1 |
| **Non-covered Entries/Exit** | | | |
| High Activity | 1.0 | 1.0 | 2.0:1 |
| Mid-Low Activity | 1.0 | 0.6 | 2.0:1 |

2) Parking Lots – The IES RP-33-14 does not give specific guidelines for parking lots. These values are taken from the previous version RP-33-99.

**Table 3 - IES Recommended Illumination Levels for Parking Lots**

| Value | Basic Illumination | Enhanced Security |
|---|---|---|
| Minimum Horizontal | 0.2 fc | 0.5 fc |
| Max/Min Ratio | 20:1 | 15:1 |
| Minimum Vertical | 0.1 fc | 0.25 fc |

3) Pathways and Bikeways

**Table 4 - IES Recommended Illumination Levels for Pedestrian Paths**

| Type | Minimum Average Horizontal | Minimum Average Vertical |
|---|---|---|
| Sidewalks and Bikeways (Roadside) | 1.0 fc | 2.2 fc |
| Walkways, Stairways and bikeways distant from roadways | 0.5 fc | 0.5 fc |
| Pedestrian Tunnels | 4.3 fc | 5.4 fc |

## 5. GOING BEYOND INDUSTRY STANDARDS FOR THE UNIVERSITY

In developing a University Standard for Exterior Lighting, the need to require levels above and beyond the industry standards should be considered, and was requested by Rowan University. Industry standards have been established for a safe and well-lit environment, but due to the nature of a University campus and the amount of activity at all hours of the night, increasing all required illumination levels to 2-3 times the industry standard, depending per area type on the level of industry standard, is recommended. Anything in excess of 3 times the industry standard begins to be more than necessary and a waste of energy. The energy code adopted by the State of New Jersey must still be met. With LED light fixtures, approximately 2-3 times industry standards are currently very achievable while still meeting the energy code.

These Illumination levels to be increased would be horizontal and vertical averages, as well as any required minimums. For uniformity ratios, it would be recommended to keep any max/min ratio under 10:1 at that level for University standards, and reduce the required uniformity for parking lots to at least 12:1 max/min.

The use of new technologies such as LED luminaires and smart controls such as Smart City technology are not only recommended, but often being used by many municipalities and large campuses. Smart City technologies can integrate lighting with the following:

A. Emergency Response
B. Security Integrated System
C. Information Interface Portals
D. Dimming

## 6. ROWAN UNIVERSITY LIGHTING STANDARDS

A. University Required Illumination Levels

**Table 5 – University Required Illumination Levels by Area Type**

| Area Type | Horizontal Average | Minimum | Max/Min | Average/Min | Vertical Average |
|---|---|---|---|---|---|
| Parking Lot | 1.5fc | 0.5fc | 12:1 or less | No requirement | No requirement |
| Sidewalks and Bikeways (Roadside) | 2.0fc | 0.5fc | No requirement | No requirement | 4.0fc |
| Walkways, Stairways and bikeways distant from roadways | 1.5fc | 0.5fc | No requirement | No requirement | 1.5fc |
| Pedestrian Courtyards | 1.5fc | 0.5fc | 12:1 or less | No requirement | 1.5fc |
| Drives | 1.5fc | No requirement | No requirement | 4:1 or less | No requirement |
| Pedestrian Crosswalks | 2.0fc | 1.0fc | No requirement | No requirement | 4.0fc |
| Canopied Building Entrances | 5.0fc | No requirement | No requirement | 2.0:1 or less | 2.0fc |
| Non-canopied Building Entrances | 3.0fc | No requirement | No requirement | 2.0:1 or less | 2.0fc |

B. Additional calculation requirements:

1) Coordinate with University Security for additional requirements for security cameras.
2) Point spacing for computer illumination calculations shall be no greater than 10ft x 10ft for parking lots and large pedestrian areas. Point spacing for pathways and sidewalks shall be no greater than 5ft down the length of the path. One set of points may be allowed down the center of a paths and sidewalks with a width under 8ft. Any path or sidewalk with a greater width shall have a grid with a spacing no greater than 5ft x 5ft.
3) Provide statistics summaries for each area, further broken down by the area types listed in the chart above. All contributing points shall fall within the area defined. When delineations between calculation zones are not clearly defined on plan with curb lines or edge of paving lines, show a labeled bounding line around each calculation zone.
4) Light Loss Factors – At a minimum, the following factors shall be included. The designer should consider all other factors that could impact the end of life illumination levels of the lighting system for each specific application and discuss with the University. Present a short narrative with calculations with all factors used and the derivation of each.
    a. Dirt Depreciation Factor – A minimum 0.90 should be used, but the designer shall consult the manufacturer for their recommendation.
    b. Light depreciation factor – This factor shall be determined by using LM-80 data and TM-21 calculator provided by the manufacturer, using a depreciation matching 65,000 hours of operation, unless otherwise determined by the University for a specific application. A lesser total hours of operation can be used to match 15 years of operation if it can be demonstrated that the

proposed approved control system will operate the lighting system less than 4,300 hours a year.

5) Light Pollution
    a. Spill off University property – Lighting calculations shall meet current municipal ordinances for spill onto other properties. No spill points shall be incorporated into any calculation zone statistics summery. Show all points off University property out to at least one row of 0.0 fc values.
    b. For drives and sidewalks adjacent to public roadways, lighting systems shall meet the vailing luminance ratio requirements in AASHTO Roadway lighting guide for applicable road type listed on table 3-5a.
    c. B.U.G. (Backlight/Uplight/Glare) Rating – Luminaires may not exceed the B.U.G. rating as shown in Table 6.

**Table 6 – University Required Maximum B.U.G. ratings**

| Mounting Height/Area Type | Backight | Uplight | Glare |
|---|---|---|---|
| Under 20ft/Campus Interior | B4 | U2 | G4 |
| Under 20ft /Adjacent to Property Line | B2 | U2 | G2 |
| Over 20ft/Campus Interior | B4 | U1 | G2 |
| Over 20ft /Adjacent to Property Line | B1 | U1 | G2 |

C. Controls
    1) Exterior lighting shall be controlled with a photocell controlled contactor.
    2) Photocells shall be mounted on the northern side of buildings where possible or facing north as close to the northern side of the building as possible.
    3) Controls of sports lighting shall be discussed with the University for each application.
    4) Exterior lighting controls shall adhere to the latest energy code adopted by the State of New Jersey.

D. Mounting Height
    1) Luminaires shall not be mounted higher than 30 feet above grade.
    2) Luminaires shall not be mounted higher than any building within 100 feet.
    3) Building mounted luminaires are exempt.
    4) Sports lighting is exempt.

## 7. RECOMMENDATIONS

Recommendations are ordered and numbered to match the existing conditions descriptions in section 2.

A. Parking Lots

In general, recommendations of **Priority 1** are areas that need a lot of remediation to correct safety and security issues. These will most likely not have simple remediation solutions, but are a great enough concern to quickly address. In general, recommendations of **Priority 2** are areas that need limited remediation, or are areas that have simpler solutions than Priority 1.

In general, recommendations of **Priority 3** are well lit enough to not warrant immediate remediation for safety and security. They may not meet University standards, but at least meet industry standards, and with no obvious safely or security concerns. These areas are recommended to reserve upgrading to LED until all Priority 1 and 2 areas are considered.

1) Lot D (Priority 1) – Sheets 1A and 2A
   Being that this lot is adjacent to a major sports field, These lights have been pointed out to be owned and maintained by Atlantic City Electric.

2) Lot C (Priority 2) – Sheet 1A
   Being that the half of the parking lot adjacent to Carpenter Street is well lit and uniform on its own, it would be recommended to at least supplement the existing lighting with additional new lighting adjacent to the stadium so that the illumination levels are more consistent across the lot. A further step would be to replace the existing flood lights as well. This would could cut down on the glare from the flood lights, as well as fix the inconsistent color temperature. These lights have been pointed out to be owned and maintained by Atlantic City Electric.

3) Lot O (Priority 1) – Sheets 1B and 2B
   It would be recommended to replace all existing luminaires because the majority of this parking lot is under-lit. Existing poles and foundations may be able to be reused. Additional luminaires may be required for the park area.

4) Lot B (Priority 3) – Sheets 1B and 1C
   It would be recommended to leave this lot as it is, until it is deemed ready to update to LED light fixtures. There is not a simple fix for this lot to correct the higher than accepted max/min ratio. That high ratio is not ideal, but in this case, does not have a major impact on safety to warrant immediate remediation.

5) Edgewood Lot (Priority 1) – Sheets 1C and 1D
   The first recommended remediation would be to trim the trees in this area and re-evaluate the illumination levels. But it does not appear that the luminaires are in such and condition and output that that remediation alone would be able to correct the low light levels. It would be recommended to replace then all existing luminaires because the majority of this parking lot is under-lit. Existing poles and foundations may be able to be reused, baring no issues with trees in the curbed islands.

6) Chestnut Lot (Priority 1) – Sheet 1D
   It would be recommended to replace then all existing luminaires because the poor

illumination levels. Due to the lower illumination levels than most of the parking lots, it is also recommended to prioritize this lot ahead of the other Priority 1 lots. Existing poles and foundations may be able to be reused.

7) Lot X (No Priority) – Sheets 1E and 1F
   Due to the luminaires in this area having been upgraded to LED, and the quality of the lighting levels, no remediation is recommended.

8) Lot D1 & D2 (Priority 2) – Sheet 1A
   It would be recommended for the University to assess how critical it is to upgrade this lot's lighting levels from industry standards to University standards. This lot is moderately lit. Though it's uniformity is higher than recommended, there are no excessively dark spots.

9) Lot M (Priority 3) – Sheets 2B and 2C
   Though this lot is not quite to University standards, and there are some glare issues due to the use of flood lights, there are no major issues with the lighting levels to impact safety enough to prioritize this lot any higher. There is also no simple solution to bringing this lot up to University standards without replacing at least all of the flood lights with new luminaires.

10) Lot W (Priority 2) – Sheet 2C
    One additional light pole in the area of low levels, could increase those levels and bring the minimum and max/min ratio up to acceptable levels.

11) Student Center Loading Dock (Priority 1) – Sheets 2D and 3D
    Due to the lack of any illumination in this area, it is recommended to install luminaires at this location to meet University standards, and to set this area a higher priority than others listed as Priority 1.

12) Lot K (Priority 2) – Sheets 2D and 2E
    One additional light pole in the corner with low levels, could increase those levels and bring the minimum and max/min ratio up to acceptable levels. Due to the use of this lot, the use of flood lights is more acceptable than a typical parking lot open to the public or general University student body and staff. The replacement of the flood lights with a luminaire type with less glare is not as critical for this application, though should be investigated whenever this lot is updated to LED.

13) Lot U (Priority 3) – Sheets 2D and 3D
    Due to the quality of the lighting levels, no remediation is recommended, except for the eventual upgrade to LED.

14) Lot J (Priority 3) – Sheets 2D, 2E and 3D
    Due to the quality of the lighting levels, no remediation is recommended, except for the eventual upgrade to LED. The higher than recommended light levels are not so excessive to warrant immediate remediation, especially if there have not been any previous complaints.

15) Lot T (Priority 2) – Sheets 3E
    The lighting levels found at this lot would normally warrant a Priority 3. But due to the

small size of this lot and few required lights to illuminate it, this lot's priority was raised from 3 to 2 because of the simplicity of upgrading to LED and to University standards.

16) Lot F (Priority 1) – Sheets 4A and 4B
It would be recommended to replace all existing luminaires because the majority of this parking lot is under-lit. Existing poles and foundations may be able to be reused. This lot may be downgraded to a Priority 2 only because of the small number of poles needed to illuminate it, it would not be costly to complete.

17) Lot A (Priority 2) – Sheets 4A and 5A
This lot should be addressed sooner than other Priority 2 areas due to its low levels, but from an initial review, it appears this lot could be upgraded to University standards with the addition of new luminaires, and not a complete re-design. Further evaluation will be needed to determine that.

18) Lot G (Priority 1) – Sheets 4C
It would be recommended to replace then all existing luminaires because the poor illumination levels. Due to the lower illumination levels than most of the parking lots, and the tucked away location, it is also recommended to prioritize this lot ahead of the other Priority 1 lots. Existing poles and foundations may be able to be reused.

19) Lot Z-1 (Priority 1) – Sheets 4C and 5C
It would be recommended to replace then all existing luminaires because the poor illumination levels. Due to the lower illumination levels than most of the parking lots, and the tucked away location, it is also recommended to prioritize this lot ahead of the other Priority 1 lots. Existing poles and foundations may be able to be reused.

20) Lot H (Priority 2) – Sheets 3C, 4C and 4D
With the addition of one new luminaire at the southern portion of the parking lot, it is possible to increase the lighting levels to an acceptable, if not quite University standards.

21) Lot P (Priority 2) – Sheets 4D and 5D
This lot is only deficient in one small area by the entrance and the Carriage House. The addition of one new pole in this area could remediate that deficiency.

22) Lot R (No Priority) – Sheet 5D
This lot needs no immediate remediation, and is already lit with LED luminaires.

23) Lot Y (Priority 2) – Sheet 6C
This small lot could be upgraded to University standards with the addition of one new pole mounted light fixture and a new building mounted fixture.

B. Pathways
In general, a point reading of 0.0 fc should be addressed. Any area with more than (1) point reading of 0.1 fc in succession should also be addressed. These areas could be due to a luminaire whose lamp has failed, or in any other way has failed to operate correctly. Any such areas where a faulty luminaire is not the issue, or paths with more than (2) successive point readings under 0.4 fc, should also be reviewed for remediation.

The following recommendations are more specific to each area. **Priority 2** will generally have

a mix with issues and those without, or with a number of areas with simpler remediation suggestions. **Priority 1** will be primarily areas that need more immediate attention. **Priority 3** will be similar to that for parking lot recommendations.

1) Football Area Paths (Priority 2) – Sheets 1A and 2A
   Paths with little or no illumination would not require many new poles to improve to acceptable lighting levels.

2) Baseball Area Paths (Priority 2) – Sheets 1B, 1C, 2B and 2C
   Paths with little or no illumination would not require many new poles to improve to acceptable lighting levels.

3) EPA Area Paths (Priority 1) – Sheets 1C, 1D, 1E, 2C and 2D
   There are enough areas with little to no illumination to warrant greater attention and need for upgrading.

4) Holly Point Area Paths (Priority 3) – Sheets 1D, 1E, 1F, 2D and 2E
   With the exception of a few lesser than acceptable sections, this area is primarily in need of no remediation.

5) Rowan Hall Area Paths (Priority 1) – Sheets 2A, 2B, 3A, 3B, 4A and 4B
   With the exception of a few acceptable sections, this area is primarily in need of a great deal of remediation. Because of the remoteness of some sections, this area should get immediate attention.

6) Robinson Area Paths (Priority 1) – Sheets 2B, 2C, 3B and 3C
   There are enough areas with little to no illumination to warrant greater attention and need for upgrading.

7) Meditation Walk (Priority 3) – Sheets 3B, 3C and 4B
   This walk should be evaluated again when complete, but it is anticipated that it will need no remediation based on readings taken in completed sections.

8) Science Hall Area Paths (Priority 3) – Sheets 3B, 3C, 4B and 4C
   With the exception of a few lesser than acceptable sections, this area is primarily in need of no remediation.

9) Student Center Courtyard (Priority 1) – Sheet 3C
   Due to its small size and few additional luminaires that would be required to remediate, this area could be considered a Priority 2, but considering its central location and heavy foot traffic, as well as a number of seating areas, it is recommended to keep this area Priority 1.

10) Evergreen Hall Area Paths (Priority 1) – Sheets 3D, 3E and 4D
    With the exception of the western end of this area, which is primarily acceptable, the majority of this area is in need a lot of additional illumination.

11) Townhouse Paths (Priority 1) – Sheets 4B, 4C, 5B and 5C
    This area for the most part meets University standards.

12) Hawthorn Hall Courtyard (Priority 3) – Sheet 4C
Though primarily only at industry standards, this area does not have any safety or security concerns to warrant immediate remediation.

13) Laurel Hall Area Paths (Priority 2) – Sheet 4D
Paths with little or no illumination would not require many new poles to improve to acceptable lighting levels.

14) Bunce Hall Area Paths (Priority 1) – Sheets 4C, 4D, 5C, 5D, 6C and 6D
There are enough areas with little to no illumination to warrant greater attention and need for upgrading.

**Table 6a – Summery of Recommendations – Parking Lots**

| Description | Priority |
|---|---|
| **Lot D** | **1** |
| **Lot C** | **2** |
| **Lot O** | **1** |
| **Lot B** | **3** |
| **Edgewood Lot** | **1** |
| **Chestnut Lot** | **1** |
| **Lot X** | **NA** |
| **Lot D1 & D2** | **2** |
| **Lot M** | **3** |
| **Lot W** | **2** |
| **Student Center Loading Dock** | **1** |
| **Lot K** | **2** |
| **Lot U** | **3** |
| **Lot J** | **3** |
| **Lot T** | **2** |
| **Lot F** | **1** |
| **Lot A** | **2** |
| **Lot G** | **1** |
| **Lot Z-1** | **1** |
| **Lot H** | **2** |
| **Lot P** | **2** |
| **Lot R** | **NA** |
| **Lot Y** | **2** |

**Table 6b – Summery of Recommendations – Pathways**

| Description | Priority |
|---|---|
| Football Area Paths | 2 |
| Baseball Area Paths | 2 |
| EPA Area Paths | 1 |
| Holly Point Area Paths | 3 |
| Rowan Hall Area Paths | 1 |
| Robinson Area Paths | 1 |
| Meditation Walk | 3 |
| Science Hall Area Paths | 3 |
| Student Center Courtyard | 1 |
| Evergreen Hall Area Paths | 1 |
| Townhouse Paths | 1 |
| Hawthorn Hall Courtyard | 3 |
| Laurel Hall Area Paths | 2 |
| Bunce Hall Area Paths | 1 |

## 8. GLOSSERY OF TERMS

**Airglow** faint emissions of light in the earth's upper atmosphere caused by a number of chemical reactions mainly involving oxygen and nitrogen.

Mie scattering: scattering in the atmosphere due to large particles independent of wavelength.

**backlight** the percent luminaire lumens distributed behind a luminaire between zero degrees vertical
(nadir) and 90 degrees vertical. The backlight solid angle is further subdivided into sub-angles:
BL (low): from 0 to 30 degrees vertical
BM (mid): from 30 to 60 degrees vertical
BH (high): from 60 to 80 degrees vertical
BVH (very high): from 80 to 90 degrees vertical

**BUG rating** the IES rating system for luminaires that measures Backlight, Uplight, and Glare.

**candela, cd** the SI unit of luminous intensity, equal to one lumen per steradian (lm/sr). Formerly candle.

**color rendering index** a method to determine how well a light source's illumination of eight sample
patches compares to the illumination provided by a reference source.

**color temperature** (or correlated color temperature CCT) The color temperature of a light source is
determined by comparing its chromaticity with that of an ideal black-body radiator. The temperature
(usually measured in Kelvin (K)) at which the heated black-body radiator matches the color of the light
source is that source's color temperature.

**Community Responsive Design** an inclusive process that considers the concerns of all the community
to ensure that the end result is planned, coherent, and satisfactory for the community.

**forward light** the percent luminaire lumens distributed in front of a luminaire between zero degrees
vertical (nadir) and 90 degrees vertical. The forward light solid angle is further subdivided into sub-angles:
FL (low): from 0 to 30 degrees vertical
FM (mid): from 30 to 60 degrees vertical
FH (high): from 60 to 80 degrees vertical
FVH (very high): from 80 to 90 degrees vertical

**glare** the sensation produced by luminance within the visual field that is sufficiently greater than the
luminance to which the eyes are adapted causing annoyance, discomfort, or loss in visual performance
and visibility.

**illumination** the act of illuminating or state of being illuminated.

**light pollution** the added sky brightness caused by the scattering of electric light into the atmosphere.
Often referred to as sky glow.

**light trespass** effect of light that strays from the intended purpose and becomes an annoyance, a
nuisance, or a determent to visual performance. As such, light trespass should always be considered
negative, unlike spill light which can have positive or negative attributes. Light trespass is the encroachment of light causing annoyance, loss of privacy, or other nuisance.

**lighting zone** a scale (descriptive and/or prescriptive) that designates degrees of ambient light. Lighting zones are determined by the community. Refer to lighting zone guidelines in the Model Lighting Ordinance User Guide.

**lumen, lm** the SI unit of luminous flux. It is defined as the amount of light which falls upon an area of one square meter, every point of which is one meter distant from a source of one candela. Therefore, a one candela source produces a total of 12.57 lumens. (RP-33 note: Initial lumens is the maximum lumen
output when the equipment is new, while maintained lumens occur when the equipment has aged or has decreased light due to dirt, referred to as lumen depreciation.)

**luminaire (outdoor lighting fixture)** a complete lighting unit consisting of light source(s) together with
the parts designed to distribute the light, to position and protect the light sources, and to connect light
sources to the power supply.

**luminaire (solid angle)** lumens the distribution of light from a luminaire measured in lumens in a par-ticular solid angle – high angle light, forward light, and back light including the luminous intensity (cd)
at the angle limits. (Also referred to as zonal lumens)

**luminance** relates to the quantity of light reflected or emitted toward an observer, what an observer sees.

**luminous intensity, $I = d\Phi/d\omega$ (of a point source of light in a given direction)** the luminous flux per
unit solid angle in the direction in question. Hence, it is the luminous flux on a small surface centered
on and normal to that direction divided by the solid angle (in steradians) that the surface subtends at
the source. Luminous intensity can be expressed in candelas (cd) or in lumens per steradian (lm/sr).

**mounting height** the vertical distance between a roadway, or other surface and the center of the
apparent light source of the luminaire.

**nadir** In the lighting discipline, nadir is the angle pointing directly downward from the luminaire, or 0°.
Nadir is opposite the zenith.

**obtrusive light** light pollution, excess or obtrusive light created by humans.

**photometric efficiency** the ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the
light sources used therein.

**photometry** the measurement of quantities associated with light. Note: Photometry can be either
visual, in which the eye is used to make a comparison, or physical, in which measurements are made
by means of physical receptors.

**Purkinje shift** the displacement of the maximum sensitivity of the eye towards the blue end of the
spectrum at low levels of ambient illumination. It occurs in a wide variety of vertebrates.

**Rayleigh scattering** the scattering of electromagnetic radiation by particles with dimensions much smaller than the wavelength of the radiation, resulting in angular separation of colors and responsible
for the reddish color of sunset and the blue of the sky. Rayleigh scattering is much stronger for short-wavelength (blue) light.

**sky glow** the brightening of the night sky that results from the reflection of radiation (visible and non-visible), scattered from the constituents of the atmosphere (gaseous molecules, aerosols, and particulate matter), in the direction of the observer. It comprises two separate components:

*natural sky glow* that part of the sky glow which is attributable to radiation from celestial sources and luminescent processes in the earth's upper atmosphere.

*artificial sky glow* that part of the sky glow which is attributable to man-made sources of radiation (e.g., outdoor electric lighting), including radiation that is emitted directly upwards and radiation that is reflected from the earth's surface.

**SPD** spectral power distribution (of a light source).

**trapped light** the percent light source lumens or luminaire lumens that are not emitted from the luminaire. Trapped light is the difference between one hundred percent and the photometric efficiency or the total light source lumens minus the lumens emitted from the luminaire.

**uplight (upward component)** the percent luminaire lumens distributed above a luminaire between 90
and 180 degrees vertical. The uplight solid angle is further subdivided into sub-angles:
UL (low): from 90 to 100 degrees vertical
UH (high): from 100 to 180 degrees vertical

**vertical angle** angles referenced from nadir; for forward light 0-90 degrees vertical in front of the luminaire; for back light 0-90 degrees vertical in back of the luminaire; and for uplight 90-180 degrees vertical distributed around the luminaire.

**visual acuity** a quantitative measure of the ability to identify black symbols on a white background at a
standardized distance as the size of the symbols is varied. Background adaptation luminance can affect
visual acuity.

**Zenith** as applied to luminaires, the point directly above a luminaire (90 degrees vertical, 90 degrees horizontal).