I. INTRODUCTION

The purpose of this memorandum is to establish lighting criteria for walkways within the project limits of the City of Charlottesville Pedestrian Lighting Study. The project limits are divided into two study areas defined by the City:

- **Area A “Downtown”** – Sidewalks within the area bound by Ridge McIntire Road on the west, High Street on the north, 9th Street NE/SE on the east, and Monticello Avenue on the south.
- **Area B “UVA”** – Sidewalks within the area bound by Emmet Street on the West, University Circle/Grady Avenue on the north, 10th Street NW on the east, and University Avenue/Main Street on the south.

Prior to establishing light level criteria, it is beneficial to have an understanding of the relevant codes, guidance documents, and factors that impact the pedestrian lighting environment. As such, this memo includes discussion on various pedestrian lighting design considerations, a summary of applicable State lighting standards, and examples of different lighting scenarios and associated light levels. This background information serves as the basis for establishing the recommended light level criteria.

This memo is organized as follows:

- **Pedestrian Lighting Design Considerations** – This section contains an overview of human vision factors, land use, level of pedestrian activity, stray light and security concerns, and how these factors might be applied to pedestrian lighting design in the City of Charlottesville.
- **State of Virginia Lighting Standards** – This section provides an overview of State outdoor lighting codes and VDOT lighting criteria.
- **IES RP-8-14 Roadway Lighting** – This section provides a summary of pedestrian area lighting criteria included in the IES RP-8-14.
- **Light Level Examples** – This section includes photos to help visualize various light levels and light sources in different land uses.
- **Proposed Walkway Lighting Criteria** – The proposed horizontal and vertical illuminance recommendations are outlined in this section.
• **Next Steps** – The next steps of this study are outlined in this section, including follow-up meetings to discuss the recommended criteria and how the existing light levels compare to the recommended criteria.

**A. Literature Review and Key Findings**

As part of this process, relevant lighting codes, design manuals and IES documents were reviewed. These documents include:

- Code of Virginia;
- VDOT Traffic Engineering Design Manual 2014;
- IES Roadway Lighting Recommended Practice (RP-8-00 and RP-8-14);
- IES Lighting for Exterior Environments Recommended Practice (RP-33-14);
- IES Lighting Handbook, 10th Edition;
- IES Guidelines for Security Lighting for People, Property and Public Spaces (G-1-03);
- IES TM-15-11 Luminaire Classification System for Outdoor Luminaires; and
- Relevant Sidewalk Criteria Used by Other Municipalities.

This memo draws from the literature review and includes relevant findings throughout. One fundamental finding that should be understood prior to reading the memo is that the IES RP-8-14 *Roadway Lighting*, authored by the IES Roadway Lighting Committee, is the sole IES document that provides specific light level criteria for sidewalks adjacent to roadways. While other IES publications discuss pedestrian area lighting, the RP-8-14 is intended to be used as the basis of design for sidewalks adjacent to roadways.

For a detailed summary of the literature review, refer to Appendix A.
II. PEDESTRIAN LIGHTING DESIGN CONSIDERATIONS

Pedestrian lighting design must consider a variety of factors in order to establish the appropriate lighting solution for a given location. This section contains discussion on several factors that are important to pedestrian lighting design, including:

- Human Vision Factors
- Adjacent Land Use and Level of Pedestrian Activity
- Stray Light
- Security Concerns
- Roadway Lighting vs. Pedestrian Lighting Design

Recommendations provided by the IES for several of these considerations, including mesopic adjustment factors, visual age, lighting zones and target illuminance, have not yet been fully studied by the IES Roadway Lighting Committee and incorporated into the recommended pedestrian light level criteria included in the RP-8-14. That said, summaries of these items are provided in this section to give the City of Charlottesville a better understanding of considerations that factor into selecting light level criteria.

A. Human Vision Factors

1. Spectral Considerations

In exterior environments, the human eye’s processes of visual adaptation and recognition operate in three categories of vision: Photopic, Mesopic and Scotopic. The eye has two primary light-sensing cells in the retina, known as photoreceptors, called rods and cones. Cones process visual information under daytime, or photopic light levels. Rods are used in near-complete darkness, or scotopic light levels. Photopic light levels provide excellent color discrimination. Under scotopic light levels, colors appear in black, white and gray. Between photopic and scotopic light levels is a range called mesopic, which are low, but not dark, lighting conditions. This mesopic range is similar to outdoor lighting conditions, where both cones and rods combine the photopic and scotopic response to process visual information. Table 1 provides a comparison of these three types of vision.

<table>
<thead>
<tr>
<th>Table 1: Vision Types</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photopic</strong></td>
</tr>
<tr>
<td>Vision under well-lit conditions, processed by cones.</td>
</tr>
<tr>
<td>IES defines as above an average of 5 candela per meter squared. Assuming a 25% sidewalk reflectance, this equates to a 6.2 fc average.</td>
</tr>
</tbody>
</table>
The ratio of scotopic luminance to photopic luminance in a lamp is called the S/P ratio. The higher the S/P ratio, the higher the perceived light by the human eye. Generally, lights with high S/P ratios provide sharper vision conditions. Natural daylight has an S/P ratio of 2.5. Typical S/P ratios for different light sources are contained in Table 2.

<table>
<thead>
<tr>
<th>Light Source</th>
<th>S/P Ratio</th>
<th>Scotopic Lumens/Watt</th>
<th>Photopic Lumens/Watt</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000K – 6000K LED</td>
<td>2.00</td>
<td>180</td>
<td>90</td>
</tr>
<tr>
<td>Clear Metal Halide</td>
<td>1.49</td>
<td>126</td>
<td>85</td>
</tr>
<tr>
<td>3500K Fluorescent</td>
<td>1.24</td>
<td>85</td>
<td>69</td>
</tr>
<tr>
<td>2900K Warm White Fluo.</td>
<td>0.98</td>
<td>64</td>
<td>65</td>
</tr>
<tr>
<td>Low Pressure Sodium</td>
<td>0.38</td>
<td>63</td>
<td>165</td>
</tr>
<tr>
<td>35W High Pressure Sodium</td>
<td>0.57</td>
<td>31</td>
<td>55</td>
</tr>
</tbody>
</table>

Source: [http://www.led-llc.com](http://www.led-llc.com)

The *IES Lighting Handbook* introduced the use of Mesopic adjustment factors to account for improved vision when lights have higher S/P ratios. Illuminance recommendations assume that the spectral composition of the luminances involved have an S/P ratio of 1.0. If the spectral composition is known to have a different ratio, then the *Lighting Handbook* suggests that an adjustment may be made to the recommended illuminance that accounts for the shift in peak efficacy due to mesopic adaptation.

These Mesopic adjustment factors are a function of photopic luminance and the S/P ratio, as illustrated in Figure 1. As the photopic luminance approaches 4 cd/m², the graph in Figure 1 shows the convergence to a 1.0 mesopic adjustment factor. At lower photopic luminance levels:

- S/P ratios greater than 1.0 result in adjustment factors that would lower the required illuminance.
- S/P ratios less than 1.0 result in adjustment factors that would increase the required illuminance.
The IES RP-8-14 Roadway Lighting, which is the authority on lighting design for roadways, streets, adjacent bikeways and pedestrian ways, recommends that Mesopic factors only be used to assess the luminance of off-road locations in applications for street lighting where the posted speed limit is 25 mph or less. Based on this recommendation, one could conclude that a driver, when traveling at 25mph or less, may see a pedestrian on the sidewalk in their peripheral vision clearer using an LED light source with a high S/P ratio under lower light levels. This is a key discovery. Unfortunately, the IES Roadway Lighting Committee has not provided insight as to whether those lower light levels on the sidewalk would impact the visual capacity of pedestrians seeing other pedestrians on the sidewalk. Until more research is conducted, application of Mesopic adjustment factors to recommended pedestrian way light levels is not appropriate.

In addition, due to ongoing research, the IES Roadway Lighting Committee is not recommending the factors for other applications in the right-of-way (including sidewalk lighting) at this time. Based on this assessment, it does not seem appropriate to apply Mesopic multipliers to lighting recommendations for the City of Charlottesville.

2. **Light Source and Color Rendering**

The relationship between the light source spectral distribution and visibility can be significant under outdoor lighting conditions. Mesopic vision is dominant in outdoor lighting conditions, where the eye perceives short wavelength (blue) light more easily than long-wavelength (red) light. Historically, outdoor lighting for roadways and sidewalks has used high pressure sodium, which has minimal short wavelength light. Blue-rich light sources, such as high correlated color temperature (CCT) LED, Mercury Vapor, and Metal Halide, provide broader spectral content and provide a sense of improved nighttime vision. However, the increase in short wavelength light also results in relatively higher skyglow due to the increase of Rayleigh scattering associated with short wavelength light. Rayleigh scattering is the scattering of molecules, such as nitrogen or oxygen, which occurs at high altitudes. When subjected to Rayleigh scattering, light is reflected in a number of directions, causing skyglow.
Three (3) main light sources were observed during the existing lighting inventory for this study: Mercury Vapor, High Pressure Sodium (HPS), and LED. Mercury Vapor is characterized by a poor lumen per watt output and a short useful lifespan. Due to these inefficiencies, Mercury Vapor is being phased out of the outdoor lighting industry and being replaced by either Metal Halide, HPS, or LED. Metal Halide luminaires emit a white light, with an approximate useful life of 10,000 hours. HPS is characterized by an amber colored light, with an approximate useful life of 22,000 to 24,000 hours. LED light can vary in color, and is typically rated for a minimum 50,000 hours. As the technology is rapidly evolving, manufacturers are pushing the LED useful life limits to upwards of 100,000 hours. Figure 2 below illustrates typical lumen depreciation, by light source, as a function of time.

![Lumen Maintenance Curves For Various Commercial Light Types](www.EconoLuxIndustries.com)

**Figure 2: Lumen Depreciation Curves.**
*Source: www.EconoLuxIndustries.com.*

It should be noted that Dominion Power does not supply Metal Halide luminaires. Dominion is also phasing out Mercury Vapor and replacing them with HPS. Dominion does offer LED luminaires, but at a higher upfront cost.

The main benefits of LED are:

1. Lower power consumption per lumen delivered;
2. Longer lifespan, which reduces maintenance costs; and
3. Ability to emit light in different color temperatures, resulting in a potentially higher S/P Ratio.

In terms of safety, item (3) above is important to note. Outdoor street lighting LEDs are typically a “white” light, often specified between 4000K and 4500K color temperature, providing the user with enhanced color recognition in outdoor lighting conditions where mesopic vision is prominent. This stark difference in color perception can be seen in Tables 6 through 10 in Section V. HPS is typically limited to the 2200K color temperature range. For reference, Figure 3 illustrates the different color temperatures of various light sources.
As noted in Table 2 above, a luminaire’s light source and color rendering impact its S/P ratio, which in turn can lead to adjustments in light level criteria by luminaire type. However, since the IES Roadway Lighting Committee is not recommending these Mesopic adjustment factors for sidewalks at this time, light source and color rendering do not affect light level criteria within the project limits.

Although not influencing recommended light level criteria at this time, light source and color rendering are important factors to consider. Determining the preferred light sources (LED versus HPS) or color rendering (cooler versus warmer) will be a significant part of the implementation plan, and may impact economic viability of future proposed improvements.

3. Visual Age

By the time a person reaches 65 years old, he or she may require four times the amount of light he or she required at 20 years old. In the Lighting Handbook, the IES addresses this disparity by assigning three target values to each task or application based on the average age of observers:

- At least half of observers or users are less than 25 years old (less light needed)
- At least half of observers or users are between 25 and 65 years old (normal light)
- At least half of observers or users are greater than 65 years old (more light needed)

It is assumed that at least half of Charlottesville’s demographic is within the 25 to 65 age range, and therefore no adjustment factor for age is required in developing lighting criteria. RK&K will confirm this age demographic assumption with the City.
B. Adjacent Land Use and Level of Pedestrian Activity

The impact of lighting is different in relative terms depending on the surrounding area (e.g., a lighting system using the higher end of recommended horizontal and vertical lighting levels will have a different impact in urban environments, which typically have high ambient lighting from surrounding areas, than in rural or residential environments, which typically have little to no ambient lighting from surrounding areas).

The IES RP-8-14 indirectly addresses adjacent land use and its impact on lighting levels by tying the recommended light level criteria to pedestrian activity levels. Recommended light levels vary by pedestrian activity level, with, for example, rural and residential areas requiring lower light levels then retail districts and town centers.

1. Lighting Zones

The Joint IDA/IES Model Lighting Ordinance (MLO), IES RP-33 Outdoor Environmental Lighting, and the IES Lighting Handbook establish Lighting Zones that describe different ambient lighting conditions. Light level recommendations are then tailored to specific Lighting Zones. Lighting zones in more urban areas require greater illuminances given densities of nighttime activity and a need to maintain light levels consistent with surroundings. The appropriate application of the established Lighting Zones relative to the light level recommendations in the RP-8-14 was under review by the IES Roadway Lighting Committee, who authors the RP-8-14, at the time the document was issued. While taking different ambient lighting conditions into account is important, the IES Roadway Lighting Committee has not yet provided recommendations on the appropriate roadway or sidewalk light levels restrictions for each Lighting Zone.

2. Illuminance Target Value System

Activity levels influence lighting criteria. Higher activity levels demand greater light levels. Ergo, the IES has outlined an Illuminance Determination System that includes a range of target light levels for particular tasks, areas and age groups. Target light level recommendations for pedestrian ways and bikeways are contained in Table 4 of the RP-33-14 Lighting for Exterior Environments. This table does not provide specific light level criteria for pedestrian ways, but instead refers to IES RP-8-14, Section 4.2.1, Pedestrian Areas and Bikeways, for additional information. The RP-8-14 provides specific light level criteria for pedestrian areas, but has not yet incorporated the Illuminance Target Value system into their criteria.

Additionally, in the introduction to Chapter 26, Lighting for Exteriors, of the IES Lighting Handbook, it is noted that “exterior illuminance criteria related to parking lots, parking structure, pedestrian sidewalks and paths, and street and roadway are not yet aligned with this procedure [the procedure for determining target illuminances] and remain under development at his writing”. As such, while the discussion about target illuminance throughout the Lighting Handbook and other IES guides provides valuable background information, it is not yet ready for application to pedestrian ways.

C. Stray Light

Stray Light does not influence lighting criteria, but can have a significant impact on design of proposed future lighting improvements. Stray Light, e.g., glare, light trespass, and sky-glow, are often the subject of criticism from the general public. To better understand the discussion on these issues, it is important to first have an understanding of industry terminology regarding luminaire optics.
1. **Luminaire Optics**

Prior to adopting the BUG rating system, the IES classified light patterns in five transverse distribution patterns (Figure 4) and cutoff characteristics (Figure 5). The cutoff classification was based on the amount of light emitted above the horizontal. The control of candlepower in the upper portions of the beam angles was divided into four categories: Full Cutoff, Cutoff, Semi-cutoff and Non-cutoff.

![Figure 4: IES Lighting Distribution Types.](image)

A new luminaire classification system was adopted by the IES in 2011 and is described in *IES TM-15-11 Luminaire Classification System for Outdoor Luminaires*. This system defines the distribution of light from a luminaire within three primary solid angles, including Backlight, Uplight and Glare (BUG). This system is further defined in Figure 6.

The BUG rating system, also known as the Luminaire Classification System (LCS), is meant to be used in conjunction with the IES distribution patterns (Figure 4), and to supersede the previous IES cutoff classifications (Figure 5). The previous cutoff classifications were based on intensities at or above 80 degrees. However, these cutoff classifications could not always accurately depict a luminaire’s performance. For example, there are some semi-cutoff luminaires that emit less uplight (i.e. light above the 90 degree horizontal) versus cutoff luminaires. But the semi-cutoff luminaires did not meet the intensity restrictions at 80 degrees, which resulted in a lower classification. The BUG ratings seek to clarify these types of discrepancies.

![Figure 5: IES Cutoff Classifications Source: IES RP-8-00](image)
The BUG ratings are divided into three (3) primary angles: Backlight, Uplight, and Glare. These are further divided into ten (10) secondary angles. Lumen output is measured at each of these angles to arrive at the luminaire’s BUG rating. It should be noted that a “full cutoff” luminaire would be rated as a U0. Section VI (b) below details the City and Dominion luminaires currently used within the project limits, as well as their BUG ratings. While not directly impacting lighting criteria, the BUG rating for City and Dominion luminaires may influence the design of proposed future improvements in the implementation phase of the Lighting Study.

2. Glare

Glare is a visual sensation caused by excessive brightness and is typically subdivided into two components: disability glare and discomfort glare. Disability glare results in reduced visual performance and visibility, while discomfort glare is the sensation of annoyance or pain induced by overtly bright light sources.

In the BUG classification system, glare takes into account the amount of light in the high and very high zones (60 to 90 degree zones). A 2013 study titled Pedestrian Friendly Outdoor Lighting, which was prepared for the U.S. Department of Energy, noted that glare angles for pedestrians are different than those for drivers. Traditionally, driver glare angles have been noted as being in the range of approx. 75 degree to 90 degrees from nadir. The observations gathered in this study noted that while pedestrians may be affected by glare from those angles when they are far away from the luminaire, they are most uncomfortable when that are closer to the luminaire, or the zone from 0 degrees to 75 degrees where the highest luminance elements are within or above the field of view. The study speculates that this reaction to glare may be due to the fact that pedestrians naturally look around their surroundings as they walk, putting the luminaire in the field of view as their eyes look upward. They study goes on to say that there is no glare metric that works reliably for pedestrian lighting design, making full-scale mock-ups or tests an important step for gathering feedback from users on glare.

A certain amount of luminance in higher angles is required to provide sufficient lighting for seeing faces and bodies of approaching pedestrians. Balancing those requirements while minimizing glare can be challenging. Full-cutoff luminaires are often associated with minimal amounts of glare, but they often do not provide sufficient vertical illuminance for recognizing approaching pedestrians. Semi-cutoff or non-cutoff lights provide more vertical illuminance, but often are associated with high glare, light trespass and skyglow concerns.
3. **Light Trespass**

Light trespass is the amount of light that leaves a specific site and enters another site. Minimizing unwanted light on adjacent properties and in residential windows is one goal of good lighting design. Luminaires should be selected that direct light towards areas that are desired to be illuminated (e.g., roadways and sidewalks) and minimize light trespass on adjacent properties.

4. **Skyglow**

Skyglow is the luminance that is created in the night sky by light scattered within the atmosphere and directed back towards an observer, thereby diminishing the view of the night sky. Minimizing uplight and not “over” lighting are the prescribed means for reducing skyglow.

In terms of minimizing uplight, using cutoff fixtures has long been thought of as the solution. These cutoff fixtures emit minimal light above the horizontal, and thus do not contribute to direct uplight. However, cutoff fixtures produce “residual” or “reflected” uplight. By definition, cutoff luminaires focus their output below the horizontal plane, increasing the amount of light incident on the targeted surface. This increased light on the pavement or sidewalk is reflected back to the sky. Thus, it is difficult to control skyglow even with the use of “dark sky” compliant luminaires. Studies by Lumec estimated that semi-cutoff luminaires produce nearly 40% less reflected uplight in comparison with their full cutoff counterpart fixtures. This reduction in reflected uplight more than offsets the 5% direct uplight emitted by these semi-cutoff fixtures.

D. **Security Concerns**

Security lighting is intended to protect people and property from criminal activities, while safety lighting is intended to provide safe working conditions, safe passage and identification of hazards or obstructions. While proper lighting for security can help deter crime, it should be included as a part of a well-balanced security plan that includes other security measures, such as increased surveillance, gates, enforcement, locks, etc. Before installing security lighting, it is important to first identify whether security is an issue.

For security lighting, vertical illuminance is often a more important criteria than horizontal illuminance because of the need to identify people. The *IES G-1-03 Guideline for Security Lighting for People, Property and Public Spaces* recommends a minimum vertical illuminance of 0.5 fc for facial identification. However, it should be noted that achieving a 0.5 fc vertical minimum can be difficult to achieve using roadway or pedestrian-scale lights, particularly with full cutoff fixtures that minimize uplight. The IES G-1-03 acknowledges that “while cutoff luminaires are fine for site lighting, the use of full cutoff luminaires at low mounting heights will not provide high vertical illuminance levels required for security lighting”.

Specific applications of security lighting for sidewalks adjacent to streets are not discussed in the IES G-1-03. That said, for areas where the City has security concerns, increasing vertical illuminance requirements may be one way to help deter crime.
E. Roadway Lighting versus Pedestrian Lighting Design

The traditional approach to outdoor lighting often focuses on roadway lighting, with goals that include:

- Illuminance and uniformity of light on pavement (or luminance)
- Controlling glare for drivers
- Pole spacing for economy and uniformity
- Cutoff (or BUG ratings) for dark-sky considerations
- Efficacy (lumens /watt)

While many of these goals transfer to the pedestrian environment, pedestrian focused lighting design also includes goals such as:

- Illuminance and uniformity along the path
- Controlling glare for pedestrians
- Seeing faces and bodies of adjacent pedestrians
- Feeling safe in the surrounding environment
- Minimizing unwanted light in residential windows
- Visual appearance of the luminaire, color of light, and light distribution patterns on the ground

There is no one-size-fits all lighting solution. When providing lighting for both the roadway and sidewalks with the same lighting system, balancing the needs of the driver and pedestrian can be challenging. There are tradeoffs that must be made among visual comfort, color, visibility, efficacy, cost, and other factors.
III. STATE OF VIRGINIA LIGHTING STANDARDS

In addition to having an understanding of the basic considerations involved in pedestrian lighting design, it’s also important to have an understanding of relevant State codes and standards, including the Code of Virginia and VDOT Lighting Design Criteria.

A. Code of Virginia, § 2.2.111

For lighting projects with State funding, the Code of Virginia, § 2.2.111, mandates that all outdoor lighting fixtures:

- Emit no light above the horizontal plane if the luminaire output is equal to or less than 3200 lumens.
- Emit a maximum of 2% light above the horizontal plane if the luminaire output is greater than 3200 lumens.

The Virginia Lighting Law does allow for variances from the above restrictions, when it is determined that “a bona fide operational, temporary, safety or specific aesthetic need is indicated or that such fixtures are not cost effective over the life cycle of the fixtures”.

Additionally, the law requires the Virginia Department of Transportation (VDOT) to design all lighting systems in accordance with current Illuminating Engineering Society of North America (IESNA) standards and recommended practices. Lighting systems are required to use fixtures that minimize glare, light trespass, and skyglow while providing a comfortable, visually effective, safe and secure outdoor environment in a cost-effective manner over the life cycle of the lighting system.

While this law appears to apply only to VDOT projects and projects where lights are purchased with State funding, the basic principles required by the law can be applied in the City of Charlottesville.

B. Virginia Department of Transportation (VDOT) Lighting Criteria

Virginia Department of Transportation (VDOT) lighting design criteria is contained in the VDOT Traffic Engineering Design Manual, issued in 2014. This manual recognizes the Virginia Lighting Law, and as such, defers to the Illuminating Engineering Society (IES) RP-8-00 (reaffirmed in 2005) Roadway Lighting for lighting criteria.

The VDOT Traffic Engineering Design Manual focuses on roadway lighting and does not provide specific recommendations for pedestrian lighting. While VDOT does not specifically provide pedestrian and sidewalk light level recommendations in their Traffic Engineering Design Manual, this information can be found in the RP-8-00 that VDOT uses to obtain roadway light level criteria.
IV.  IES RP-8-14 ROADWAY LIGHTING: PEDESTRIAN AREA LIGHTING CRITERIA

As noted in Section III.A, the Code of Virginia requires VDOT to design lighting systems in accordance with current IES standards and recommended practices. While VDOT uses IES RP-8-00 Roadway Lighting as their primary lighting design document, the most recent version of this document is the RP-8-14, which was published in 2014.

The IES Roadway Lighting recommended practice (RP-8-14) states the following in its introductory sentence:

“The primary purpose of this Standard Practice is to serve as the basis for design of fixed lighting for roadways, streets, adjacent bikeways and pedestrian ways.”

Additionally, many of the other IES recommended practices and guidelines defer to the IES RP-8 for sidewalk lighting criteria. As such, the recommendations provided in the RP-8-14 should serve as the basis for establishing pedestrian and sidewalk lighting criteria for the City.

The RP-8-14 recommended design method for pedestrian areas is horizontal and vertical illuminance. The light level recommendations are based on levels of pedestrian activity:

- High – Commercial areas with nighttime pedestrian activity such as town centers.
- Intermediate – Moderate night pedestrian activity in areas such as libraries and recreation centers.
- Low – Residential facilities located away from urban areas.

The RP-8-14 discusses specific average, vertical, and uniformity lighting levels for walkways, as listed in Tables 3, 4 and 5:

### Table 3: IES RP-8-14 Walkways – High Pedestrian Conflict Areas

<table>
<thead>
<tr>
<th></th>
<th>Horizontal Average (fc)</th>
<th>Horiz. Uniformity (Avg/Min)</th>
<th>Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mixed Vehicle and Pedestrian</td>
<td>2.0</td>
<td>4.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Pedestrian Only</td>
<td>1.0</td>
<td>4.0</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Source: IES RP-8-14 Table 4*

### Table 4: IES RP-8-14 Walkways – Medium Pedestrian Conflict Areas

<table>
<thead>
<tr>
<th></th>
<th>Horizontal Average (fc)</th>
<th>Horiz. Uniformity (Avg/Min)</th>
<th>Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walkways</td>
<td>0.5</td>
<td>4.0</td>
<td>0.2</td>
</tr>
</tbody>
</table>

*Source: IES RP-8-14 Table 5*
Table 5: IES RP-8-14 Walkways – Low Pedestrian Conflict Areas

<table>
<thead>
<tr>
<th></th>
<th>Horizontal Average (fc)</th>
<th>Horiz. Uniformity (Avg/Min)</th>
<th>Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural/Semi Rural Areas</td>
<td>0.2</td>
<td>10.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Low Density Residential (2 or fewer dwelling units per acre)</td>
<td>0.3</td>
<td>6.0</td>
<td>0.08</td>
</tr>
<tr>
<td>Medium Density Residential (2.1 to 6.0 dwelling units per acre)</td>
<td>0.4</td>
<td>4.0</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Source: IES RP-8-14 Table 6

The three (3) criteria listed in each table can be described as follows:

1) **Horizontal Average** – The mean of the light levels, measured in foot candles (fc), incident on the sidewalk surface of the study area.

2) **Horizontal Uniformity** – The ratio of the Average divided by the Minimum point, incident on the sidewalk surface of the study area. *Uniformity within criteria does not exceed the listed number.*

3) **Vertical Minimum** – The minimum foot candle level, measured or calculated at a height of 5’ above sidewalk grade. This measurement is taken in the direction of pedestrian travel, e.g. Northbound and Southbound for a North/South walkway

The Vertical Minimum criteria defined in (3) above is important in pedestrian lighting design. This parameter measures the amount of light incident at the pedestrian’s facial area. Simply meeting (1) and (2) above may not result in the proper vertical illumination. Figure 7 illustrates the concept of vertical illuminance.

*Figure 7: Poor (left) vs Adequate (right) Vertical Illuminance.*  
*Source: Peter Maradudin, IESNA SALC 2015*
V. LIGHT LEVEL EXAMPLES

In establishing criteria, it can be difficult to visualize proposed light levels. This section seeks to illustrate various light levels and lamp types, in different land uses, to provide the City with a better understanding of foot candle values. Tables 6 through 10 illustrate sidewalk illumination levels for residential, intermediate and commercial applications.

<table>
<thead>
<tr>
<th>Table 6: 20th St in Crystal City, Virginia</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average (fc)</td>
<td>Minimum (fc)</td>
<td>Uniformity (Avg/Min)</td>
<td>EB Vertical Minimum (fc)</td>
<td>WB Vertical Minimum (fc)</td>
</tr>
<tr>
<td>0.41</td>
<td>0.05</td>
<td>8.20</td>
<td>0.04</td>
<td>0.02</td>
</tr>
</tbody>
</table>

**Light Source:**
Metal Halide Acorn at 12’

**Pole Spacing:**
Varies 80’-110’

**Land Use:**
Residential
### Table 7: 4th St, SE – Washington, DC

<table>
<thead>
<tr>
<th></th>
<th>Average (fc)</th>
<th>Minimum (fc)</th>
<th>Uniformity (Avg/Min)</th>
<th>NB Vertical Minimum (fc)</th>
<th>SB Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.54</td>
<td>0.30</td>
<td>5.15</td>
<td>0.35</td>
<td>0.34</td>
</tr>
</tbody>
</table>

**Lighting Source:**
HPS acorn mounted at 15’

**Pole Spacing:**
75’

**Land Use:**
Residential

### Table 8: Rugby Road – Charlottesville, Virginia

<table>
<thead>
<tr>
<th></th>
<th>Average (fc)</th>
<th>Minimum (fc)</th>
<th>Uniformity (Avg/Min)</th>
<th>NB Vertical Minimum (fc)</th>
<th>SB Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.79</td>
<td>1.30</td>
<td>1.38</td>
<td>0.33</td>
<td>0.35</td>
</tr>
</tbody>
</table>

**Lighting Source:**
LED Acorn at 16’

**Pole Spacing:**
55’

**Land Use:**
Institutional
### Table 9: 12th St Pedestrian Trail – Pentagon City, Virginia

<table>
<thead>
<tr>
<th>Average (fc)</th>
<th>Minimum (fc)</th>
<th>Uniformity (Avg/Min)</th>
<th>WB Vertical Minimum (fc)</th>
<th>EB Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.70</td>
<td>0.50</td>
<td>3.41</td>
<td>0.08</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Lighting Source:** HPS Cobra Head at 25’

**Pole Spacing:** 80’

**Land Use:** Commercial

### Table 10: Pentagon City Mall – Arlington, Virginia

<table>
<thead>
<tr>
<th>Average (fc)</th>
<th>Minimum (fc)</th>
<th>Uniformity (Avg/Min)</th>
<th>NB Vertical Minimum (fc)</th>
<th>SB Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.17</td>
<td>1.25</td>
<td>1.74</td>
<td>0.70</td>
<td>0.65</td>
</tr>
</tbody>
</table>

**Lighting Source:**
- LED Teardrop at 30’
- LED Acorn at 15’

**Pole Spacing:** 60’

**Land Use:** Commercial
VI. PROPOSED WALKWAY LIGHTING CRITERIA

While there are a variety of IES guidelines and recommended practices available that discuss outdoor lighting, the only IES document that provides quantitative light level criteria for walkways is the IES RP-8-14, Roadway Lighting. The other IES documents reviewed provide informative discussion regarding target illuminance, mesopic factors, visual age, and lighting zones, but defer to the IES RP-8-14 for light level criteria. In the IES RP-8-14, the IES Roadway Lighting Committee acknowledges research and guidance in these areas, but does not incorporate any of that information into their design recommendations.

Therefore, the proposed lighting criteria for the City of Charlottesville is based on the RP-8-14 recommendations, with an “Enhanced Security” classification, which is intended for areas of significant nighttime pedestrian activity, such as adjacent to the Downtown Mall or University Avenue west of 14th St.

<table>
<thead>
<tr>
<th>Pedestrian Activity Level</th>
<th>Horizontal Average (fc)</th>
<th>Horiz. Uniformity (Avg/Min)¹</th>
<th>Vertical Minimum (fc)²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Proposed</td>
<td>RP-8-14</td>
<td>Proposed</td>
</tr>
<tr>
<td>Enhanced Security / Significant Pedestrian Activity</td>
<td>1.50</td>
<td>N/A</td>
<td>4.0</td>
</tr>
<tr>
<td>High</td>
<td>1.00</td>
<td>1.00</td>
<td>4.0</td>
</tr>
<tr>
<td>Medium</td>
<td>0.50</td>
<td>0.50</td>
<td>4.0</td>
</tr>
<tr>
<td>Low</td>
<td>0.40</td>
<td>0.40</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Notes: 1. Uniformity criteria is a “not to exceed” value.
2. Measured at 5 ft. in the direction of pedestrian travel.

Appendix B includes maps of Area A and Area B, classified by assumed level of pedestrian activity per street. These maps can serve as the basis for proposing light levels for the project limits. RK&K will coordinate with the City to confirm the pedestrian activity levels noted.

A. Achieving Minimum Vertical Illuminance

Achieving the minimum vertical illuminance values recommended by the IES RP-8-14 can be difficult. Of the 345 sidewalk segments inventoried, only 20 of those segments meet the recommended minimum vertical illuminance criteria based on assumed pedestrian activity level. Sample photometric calculations using the City’s standard 85W LED pedestrian fixture were performed to determine vertical illumination levels at various standardized pole spacing. Table 12 contains the results of the illuminance calculations. Appendix C includes the sample photometrics.
To meet the IES vertical illumination recommendation for low pedestrian activity, a maximum pole spacing of 60 feet is required. This 60 foot spacing is due to the “Cutoff” shielding of the City luminaire minimizing uplight, as well as its low 12 foot mounting height. The close pole spacing results in an average horizontal illuminance that is much higher than what is required. Table 12 illustrates that mandating high vertical illumination can result in a costly implementation, with the need for closely spaced poles, potentially resulting in higher average horizontal illuminance (i.e. light incident on the sidewalk) than what is required in order to achieve minimum vertical illuminance requirements.

Installing Dominion standard luminaires, mounted to utility poles, to meet IES vertical illumination recommendations is similarly challenging. Inconsistent utility pole locations can prevent adequate sidewalk lighting. However, Dominion does offer stand-alone lighting poles (concrete or aluminum) that could potentially be used to supplement the existing lighting network. Placement of these stand-alone poles may be difficult, due to potential utility conflicts with existing overhead utilities. Appendix D includes sample photometric calculations, using Dominion’s Standard luminaires, at various pole spacings with the resulting light levels. The minimum spacing required to meet IES recommendation for low pedestrian activity varies depending on the Dominion luminaire wattage, from 60 feet to 250 feet. However, the use of higher wattage luminaires, resulting in pole spacings of 200+ feet, would have to be evaluated on a case by case basis. These higher wattage fixtures could result in “over lighting” of the roadway, as well as increased light trespass.

**B. City and Dominion Standard Luminaires**

The lighting network within the project limits consists of both City and Dominion owned luminaires. The City fixtures are mounted to decorative light poles. The Dominion fixtures are mounted to utility or stand-alone concrete poles.

The standard lights for new installations in the City of Charlottesville, detailed in Appendix D, include the following:

- **LF – 1 - Downtown Mall Light Fixture – Type 1 – US Architectural Galaxy 300**
  
  - 250W Metal Halide, Type III Distribution, Full Cutoff, Mounted to 11’9” pole.
  
  - Installed at intersection adjacent to the Downtown Pedestrian Mall.

<table>
<thead>
<tr>
<th>Pole Spacing (ft)</th>
<th>Horizontal Average (fc)</th>
<th>Horiz. Uniformity (Avg/Min)</th>
<th>Vertical Minimum (fc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>1.37</td>
<td>1.71</td>
<td>0.08</td>
</tr>
<tr>
<td>50</td>
<td>1.65</td>
<td>1.38</td>
<td>0.13</td>
</tr>
<tr>
<td>45</td>
<td>1.79</td>
<td>1.38</td>
<td>0.17</td>
</tr>
<tr>
<td>40</td>
<td>2.06</td>
<td>1.37</td>
<td>0.28</td>
</tr>
<tr>
<td>35</td>
<td>2.37</td>
<td>1.39</td>
<td>0.53</td>
</tr>
<tr>
<td>30</td>
<td>2.82</td>
<td>1.57</td>
<td>1.24</td>
</tr>
</tbody>
</table>

Notes: 1. Luminaire mounted to 12 ft pole, with a photometric center of 13.5 ft.
• LF – 2 - Downtown Mall Light Fixture Type 2 – ELA Bowery
  o 100 Watt Metal Halide, Type III Distribution, Full Cutoff, Mounted to 14’ Pole.
  o Installed at intersections adjacent to the Downtown Pedestrian Mall.
• LF – 3 - Downtown Mall Fixture – Type 3
  o 250W Metal Halide, Type III Distribution, Full Cutoff, Mounted to 17’5’’ pole.
  o Installed at intersection adjacent to the Downtown Pedestrian Mall.
• LF – 4 - Residential Lighting Fixture – ELA Mediterranean
  o 85 Watt LED, Type V Distribution, B3-U1-G1, Mounted to 12’ pole.
  o Primarily installed in residential areas

It is desirable from a maintenance perspective to limit the variety of poles and luminaires that are in use in the City. That said, the luminaires currently available to the City may not be best suited to provide the recommended illumination for sidewalks. Additionally, in many cases, the same lights that are used to light the roadway must also provide sufficient sidewalk illumination. The City may want to consider adding new luminaires to their standard offerings that better meet light level requirements and other pedestrian and roadway lighting considerations.

The standard roadway luminaires offered by Dominion Power, detailed in Appendix E, include the following:

• Cooper Lighting – Streetworks OVH Flat Glass
  o High Pressure Sodium (70W, 100W, 150W, 250W, 400W)
  o Type III Distribution, Full Cutoff
• GE Evolve Scalable Cobra Head
  o LED (54W, 106W 244W)
  o Full Cutoff, Type III Distribution, 4000K CCT

Due to the abundance of existing utility poles within the project limits, it may be cost efficient to utilize Dominion’s infrastructure with the luminaires listed above, as compared to installing new stand-alone City lighting equipment. Additional Dominion lighting poles could also be added, to fill in the gaps caused by the inconsistent utility pole spacing within the project limits.

C. Existing Walkway Light Levels Compared to Proposed Criteria

In general, the existing light levels were mixed in satisfying the proposed criteria. These mixed observations were expected, as the primary source of lighting is roadway luminaires sporadically mounted to Dominion Power utility poles. The placement of the roadway luminaires was not designed to provide consistent lighting along the sidewalks. Appendices E, F, G, and H include charts with existing horizontal average illuminance, horizontal uniformity and vertical illuminance minimums for each street compared to the proposed criteria. Of the 345 sidewalk segments inventoried:

• 27 of 345 segments meet both the horizontal average and uniformity requirements.
• 20 of 345 segments meet the vertical illuminance requirement.
• 6 of 345 segments meet all horizontal and vertical illuminance requirements.
One of the primary issues with the existing lighting conditions was dark areas due to inconsistent location of Dominion luminaires. Another factor contributing to these dark areas were Dominion luminaires being past their useful life span, and in need of replacement. The measured dark areas resulted in averages, uniformities and vertical minimums below the proposed criteria.

Noteworthy areas with substandard light levels are listed in Table 13.

<table>
<thead>
<tr>
<th>Roadway</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area A – Downtown</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Street</td>
<td>7th Street, NE</td>
<td>Preston Avenue</td>
</tr>
<tr>
<td>Jefferson Street</td>
<td>All Sidewalks</td>
<td></td>
</tr>
<tr>
<td>Market Street</td>
<td>All Sidewalks</td>
<td></td>
</tr>
<tr>
<td>Water Street</td>
<td>Main Street</td>
<td>2nd Street SW</td>
</tr>
<tr>
<td></td>
<td>1st Street SW</td>
<td>2nd Street SW</td>
</tr>
<tr>
<td></td>
<td>2nd Street SW</td>
<td>2nd Street SE</td>
</tr>
<tr>
<td></td>
<td>4th Street SE</td>
<td>5th Street SE</td>
</tr>
<tr>
<td>9th Street NE</td>
<td>Majority of Sidewalks</td>
<td></td>
</tr>
<tr>
<td>Area B – UVA / The Corner</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W. Main Street</td>
<td>Jefferson Park Avenue</td>
<td>Hospital Drive</td>
</tr>
<tr>
<td></td>
<td>12th ½ Street NW</td>
<td>13th Street NW</td>
</tr>
<tr>
<td></td>
<td>11th Street SW</td>
<td>Jefferson Park Avenue</td>
</tr>
<tr>
<td>Grady Avenue</td>
<td>Rugby Road</td>
<td>12th Street NW</td>
</tr>
<tr>
<td>Gordon Avenue</td>
<td>All Sidewalks</td>
<td></td>
</tr>
<tr>
<td>Wertland Street</td>
<td>Majority of Sidewalks</td>
<td></td>
</tr>
<tr>
<td>14th Street NW</td>
<td>All Sidewalks</td>
<td></td>
</tr>
<tr>
<td>Rugby Road</td>
<td>University Way</td>
<td>Grady Avenue</td>
</tr>
</tbody>
</table>
VII. NEXT STEPS

A. Finalize Light Level Criteria

RK&K will meet with City representatives to discuss the proposed light level criteria. Items for discussion include:

- Proposed horizontal and vertical illuminance criteria based on IES RP-8-14 pedestrian activity levels
- Pedestrian activity level assumptions for each street in the study area
- Comparison of existing light level readings to recommended light level criteria
- Ability to achieve recommended light levels using the City’s existing family of luminaires

B. Develop Improvement Plan

In the next phase of the Lighting Study, RK&K will develop an Improvement Plan, which will prioritize lighting upgrades for selected segments within the project limits. The improvements will be prioritized, considering lighting deficiencies, crime statistics, and pedestrian crashes amongst other factors. Items such as capital costs (either from new City owned light poles or additional Dominion Power leased lights), operating and maintenance costs, potential for right-of-way acquisition, utility impacts, design costs, added fixed object hazards, and light trespass will be considered.

C. Intersection Lighting Design

As requested by the City, RK&K will recommend lighting improvements for fifteen (15) intersections along Market Street and Water Street. We will work with the City to determine the appropriate lights to be installed. RK&K will conduct photometric analysis and develop concept plans for the lighting improvements. Construction plans will not be developed for this effort, but can be accomplished through an additional task order if required.
LIST OF APPENDICES

Appendix A – Lighting Literature Review

Appendix B – Pedestrian Activity Level Maps

Appendix C – Sample Lighting Calculations with City 85W LED Luminaire

Appendix D – Sample Lighting Calculations with DVP HPS and LED Luminaires

Appendix E – City Standard Luminaires

Appendix F – Dominion Power Standard Luminaires

Appendix G – Area A East/West Streets Existing Light Levels versus Proposed Criteria
  o High Street.............................................. G1 - G4
  o Jefferson Street ................................. G5 - G8
  o Market Street ................................. G9 - G12
  o Water Street ................................. G13 - G16
  o Garrett Street ................................. G17 - G20
  o Monticello Avenue ......................... G21 - G24
  o Preston Avenue ................................. G25 - G26
  o Old Preston Avenue ......................... G27 - G28
  o Main Street ................................. G28 - G30
  o South Street ................................. G31 - G32
  o Hilton Avenue ................................. G33 - G34
  o Belmont Avenue ................................. G35 - G36
Appendix H – Area A North/South Streets Existing Light Levels versus Proposed Criteria

- 9th Street NE............................................ H1 - 4
- 8th Street NE........................................... H5 - H6
- 7th Street NE........................................... H7 - H8
- 6th Street NE/SE ...................................... H9 - H12
- 5th Street NE........................................... H13 - H14
- 4th Street NE/SE ..................................... H15 - H18
- 3rd Street NE/SE ..................................... H19 - H22
- 2nd Street NE/SE..................................... H23 - H26
- 2nd Street NW/SW................................. H27 - H30
- 1st Street N/S ........................................ H31 - H34
- Park Street........................................... H35 - H36
- Avon Street.......................................... H37 - H40
- Gleason Street ...................................... H41 - H42
- US 250/Ridge McIntire Road .............. H43 - H44
- Ridge Street ........................................ H45 - H46

Appendix I – Area B East/West Streets Existing Light Levels versus Proposed Criteria

- Grady Avenue ....................................... I1 - I4
- Private Alley .......................................... I5 - I6
- Gordon Avenue ...................................... I7 - I10
- Wertland Street ..................................... I11 - I14
- W Main Street ....................................... I15 - I18
- University Circle ................................... I19 - I20
- West Street ........................................... I21 - I22
- Lambeth Lane ....................................... I23 - I24
- Virginia Avenue ..................................... I25 - I26
- S/W (S of Virginia Ave) ................. I27 - I28
- Latrobe Court ......................................... I29 - I30
- John Street .......................................... I31 - I32
- Page Street ........................................... I33 - I34
- Sadler Street ......................................... I35 - I36
- University Avenue .............................. I37 - I38
Appendix J – Area B – North/South Streets Existing Light Levels versus Proposed Criteria

- 17th Street ........................................... J1 - J2
- 16th Street ......................................... J3 - J4
- 15th Street NW ................................. J5 - J8
- 14th Street NW ................................. J9 - J12
- 13th Street NW ................................. J13 - J16
- 12th ½ Street .................................... J17 - J18
- 12th Street ....................................... J19 - J20
- 11th Street ....................................... J21 - J22
- 10th ½ Street .................................... J23 - J24
- 10th Street NW .............................. J25 - J28
- University Way ........................ J29 - J30
- Ackley Lane ................................ J31 - J32
- Minor Court ................................ J33 - J34
- Elliewood Avenue .................... J35 - J36
- Chancelor Street ....................... J37 - J38
- Madison Lane ......................... J39 - J40
- Rugby Road ......................... J41 - J42