COUNCIL STAFF REPORT
CITY COUNCIL *of* SALT LAKE CITY

Item Schedule:
Briefing: August 17, 2021
Public Hearing: TBD
Potential Action: TBD

TO: City Council Members

FROM: Sam Owen, Policy Analyst

DATE: August 17, 2021

RE: 2020 Salt Lake City Street Lighting Master Plan

NEW INFORMATION

Pursuant to city resolution and state code, the City Council asked the Administration to present the Street Lighting Master Plan proposal to the City Planning Commission. The April 14, 2021 City Planning Commission forwarded the following along with a positive recommendation (i.e. a recommendation that the City adopt the plan & its accompanying documents): the Commissioner recommended that the Council "further explore the warmness of the light and the kelvin temperatures and further understand that fully." (Attachment 3)

It's the understanding of Council staff that the Department of Public Utilities is confident in the plan's current recommendations and resources in the context of color temperature. The following reconstruction of feedback and new information might be helpful and draws from a technical memo (Attachment 2) prepared by the department & its consultant on the topic of light temperature and impacts to the following categories of organic life.

The Department has communicated that the plan in its current state has adequate and appropriate control measures to mitigate impacts to humans and wildlife, such as its neighborhood-level evaluation and engagement recommendations for the process of developing lighting solutions for unique geographic areas throughout the city.

- Birds:
    - "There is no evidence that color temperature is a driving force in attraction and mortality of migratory birds." (Attachment 2, page 11, last paragraph).
- Insects:
    - "One group where color is relatively more important is insects, which are, in general, more attracted to blue, violet, and ultraviolet than yellows and reds. There are exceptions to this pattern, but studies of insect attraction to different color temperatures of LED find that lower color temperatures attract fewer insects. This relationship has been quantified and can be used to compare attraction of specific options for street lighting [citation omitted for clarity]. For nearly all [insect] organisms investigated, lower color temperatures are assessed to have reduce impacts." (Attachment 2, page 11, last full paragraph)

- Human beings:
    - "Scientists who are skeptical about the potential for outdoor to affect human health point to the intensity thresholds for melatonin suppression. Based on models of human physiology, they demonstrate that melatonin suppression is likely to be very small or not measurable below approximately 5 [lux] [this is a technical measurement for one dimension of lighting intensity]. Since outdoor lighting rarely reaches these levels within dwellings, the impact is presumed to be minimal, regardless of color temperature. This argument, however, does not extend to exposures outdoors at night and illumination under street lighting often exceeds 5 lux.

      A precautionary approach to color temperature for human circadian health relative to outdoor lighting would be to favor the use of lower color temperature lighting... which then would be balanced against other guideposts." (Attachment 2, page 11, first paragraph, emphasis added)

Finally, dark skies interests have been referenced or represented as compelling for inclusion and serious consideration in the plan. The Department's technical memo provides the following advice for technical implementation sensitive to dark skies interests: "The take-home message of this research for the Salt Lake City street lighting master plan is that for LED lamps lights to reduce light pollution compared with the previously common HPS lamps, they must be 0% uplight [sic], 50% less bright, and with a [color temperature] of no greater than 3000 K." (Attachment 2, page 12, last paragraph)

In other words, for dark skies interests & for purposes of reducing impacts to organic life, the Department has represented that the plan allows for flexible and responsive implementation of lighting strategies to address a range of concerns, such as those listed as examples above.

In the future, the Council might consider the following elements in the context of a potential motion considering adoption of the plan:

- The Council could include legislative intent language that the "dark skies" mitigation criteria for "minimum impact on light pollution" be followed uniformly & that the department provide annual or bi-annual reports on locations where that guidance has been superseded by other constraints in the course of lighting implementation.

- The Council could ask the Department to consider where impacts to wildlife can be reduced or eliminated, and provide a report on proactive lighting implementation that takes this value into account as the plan moves ahead.

- The Council might ask the Department or Administration to consider options for evaluating impacts to insect communities as a result of City street lighting changes.

- The Council might ask the Department to consider whether and where there are situations where residents or groups of residents could regularly experience lighting intensity from public fixtures at a level that would disrupt melatonin regulation.

Attachments

1. Transmittal
2. Department correlation report
3. April 14, 2021 Planning Commission minutes

PREVIOUS INFORMATION FROM THE FEBRUARY 2021 BRIEFING

ISSUE AT-A-GLANCE

The Council will receive a briefing on the proposed Street Lighting master plan. The new plan synthesizes community feedback and technical advice into a document by which the department proposes to guide street lighting improvement and maintenance throughout the city. The plan seeks to create accommodation for different lighting needs and desires throughout the city.

Adoption of the street lighting master plan does not have a budget impact for this fiscal year; however it is likely that deliberation on and adoption of the plan would pave the way for a new capital improvement program and financial strategy for the Street Lighting enterprise fund. These subsequent phases would have budgetary impacts for the enterprise fund, as well as potential impacts to ratepayers.

ADDITIONAL BACKGROUND

From the transmittal: "The most recent street lighting plan was completed in 2006. In 2013, the management of the streetlight system was transferred from the Transportation Division to the Department of Public Utilities. This transfer included changing the funding source for the operation, maintenance and capital improvements of the system from the General Fund and Special Assessment Areas [SAA] to a newly created street lighting enterprise fund."

The city provides different tiers of lighting service through the Street Lighting enterprise fund that the current system inherited from the previous SAA structure; for example, enhanced lighting areas in Rose Park, Yalecrest, and in the downtown area are assessed different rates for corresponding lighting service that varies from the basic streetlighting in most of the city. Additionally, the department maintains a private lighting program that receives a $20,000 annual grant from the general fund. This funding allows property owners to obtain matching funds from the city for private light installation in the public right-of-way. Maintenance of those private lights is the responsibility of the property owner, although the department facilitates access to a lighting contractor to support that.

From the transmittal: "During the first few years of conversion to the new LED fixtures mainly within industrial, commercial and higher density residential areas, Public Utilities received more positive feedback than negative. When installation [of new LED lights] began in the residential neighborhoods, there were more complaints. Residents were not pleased with the brightness of the lights as well as the white light emitted. The City is also proactively working on various streets projects, community improvement projects, pedestrian and bicycle friendly projects, and issues related to crime. Street lighting has a role to play in all of these endeavors." To this end, the plan also contemplates its intersections with other adopted city planning documents. (transmittal page 39 et seq., plan page 19 et seq.)

The department conducted extensive outreach through community and technical advisor groups. A more detailed report on the outreach is located in the transmittal on pages three and four. Furthermore, Council Members met in small groups with the administration to discuss the plan over the summer of 2020.

ATTACHMENTS

1. Administration transmittal

POLICY QUESTIONS

1. Council Members often receive persistent and sometimes conflicting requests from community members and community groups for lighting.
    a. The Council might be interested in hearing from the administration about how requests from community members and community groups would be vetted so that lighting implementation takes place with inclusive engagement.
    b. Council Members might wish to know how the administration proposes resolving conflicting lighting requests; e.g. would those be resolved by taking polls of property owners; what other methods would be available to determine how to move forward when requests are conflicting for one area.

2. Council Members have adopted the expectation through resolution that master plans go through a vetting process that includes review by the city's Planning Commission. The Street Lighting master plan has been in progress since before that resolution was officially adopted in 2020. The Council has adopted other planning documents since the resolution adoption that have not been reviewed by the Planning Commission.
    a. Council Members might wish to request feedback from the administration on the potential value of the Planning Commission reviewing the lighting plan before its potential adoption.

3. The Council might wish for more specific figures related to the anticipated annual budget impact when it comes to ongoing, regular implementation of the guidance in the plan.
    a. Additionally, when it comes to annual budget deliberations for the Street Lighting enterprise fund, the Council might request a more extensive oversight and guidance role when it comes to capital planning and appropriations for each coming year, not unlike the general fund capital improvement program process.
    b. An opportunity to review this enterprise fund budget in greater depth each year and throughout the interim could give the Council greater opportunity to review the capital planning and budget proposals for equity considerations.
    c. Because the technical and service requirements of the Street Lighting fund are different from the other Public Utilities enterprise funds, additional budget oversight and engagement could be more appropriate when it comes to the improvements and expansions of the city's lighting system on the basis of the proposed plan.

4. Community members have inquired about the creation of enhanced lighting areas through the general fund capital improvement program (CIP). Council Members might ask for feedback from the department about the feasibility of creating these enhanced lighting areas through general fund CIP, and then transferring the asset to the enterprise fund for maintenance and cost recovery through increased lighting fees.

APPENDIX A

The master plan proposes the following policy statements (transmittal page 18; plan page 10):

> Based on the application of planning guideposts and input of the steering and technical committees, the master plan implements the following major policies:
>
> • Street lighting will enhance safety through the implementation of industry recognized standards.

• Street lighting standards include allowances to encourage dimming strategies relating to pedestrian activity, wildlife and dark skies lighting.

• Street lighting will minimize the obtrusive effects of light at night resulting from light trespass, light pollution, and glare through the selection and placement of appropriate poles, fixtures, light type, and light levels.

• Provide pedestrian lighting in accordance with neighborhood plans and in accordance with the typologies in this plan.

• Provide street and pedestrian lighting that minimizes impacts to sensitive wildlife species.

• Select fixture types to provide dark skies protection.

• Implementation based on neighborhood and community input to determine pole, fixture type, maximum and minimum light level, and the implementation of adaptive dimming applications when appropriate.

The plan also enumerates a number of implementation priorities and steps; "proposed for highest priority are neighborhoods current underserved for street and/or pedestrian lighting based on adjacent land uses." (plan page 11) Furthermore, "high conflict areas" such as neighborhood byways and transit stations are proposed to be highest priority. High conflict refers to the potential for an area to have a diversity of uses and needs. The plan offers a helpful side-by-side table showing how the policy proposals have been revised from their 2006 predecessors. (transmittal pages 34-35, plan pages 14-15)

APPENDIX B

The plan proposes the following process for implementation (transmittal page 19, plan page 11). This process, all four steps, would take place systematically based on recommendations and classifications made in the plan.

STEP ONE:

• Identify high conflict areas in the City

• Review the current lighting map to identify underserved neighborhoods and high conflict areas

• Respond to request from community or neighborhood for lighting change

STEP TWO:

• Contact community and neighborhood representatives to identify priorities and review options according to the matrix

•Identify neighborhood-preferred option according to the matrix

STEP THREE:

• Estimate cost of preferred option

• Seek funding approval

STEP FOUR:

• Design, schedule and implement preferred option

APPENDIX C

LIGHTING LEVELS & GAPS

Implementation of Salt Lake City's current lighting policy, standards, and approach is illustrated in the streetlight density map in Figure 3.

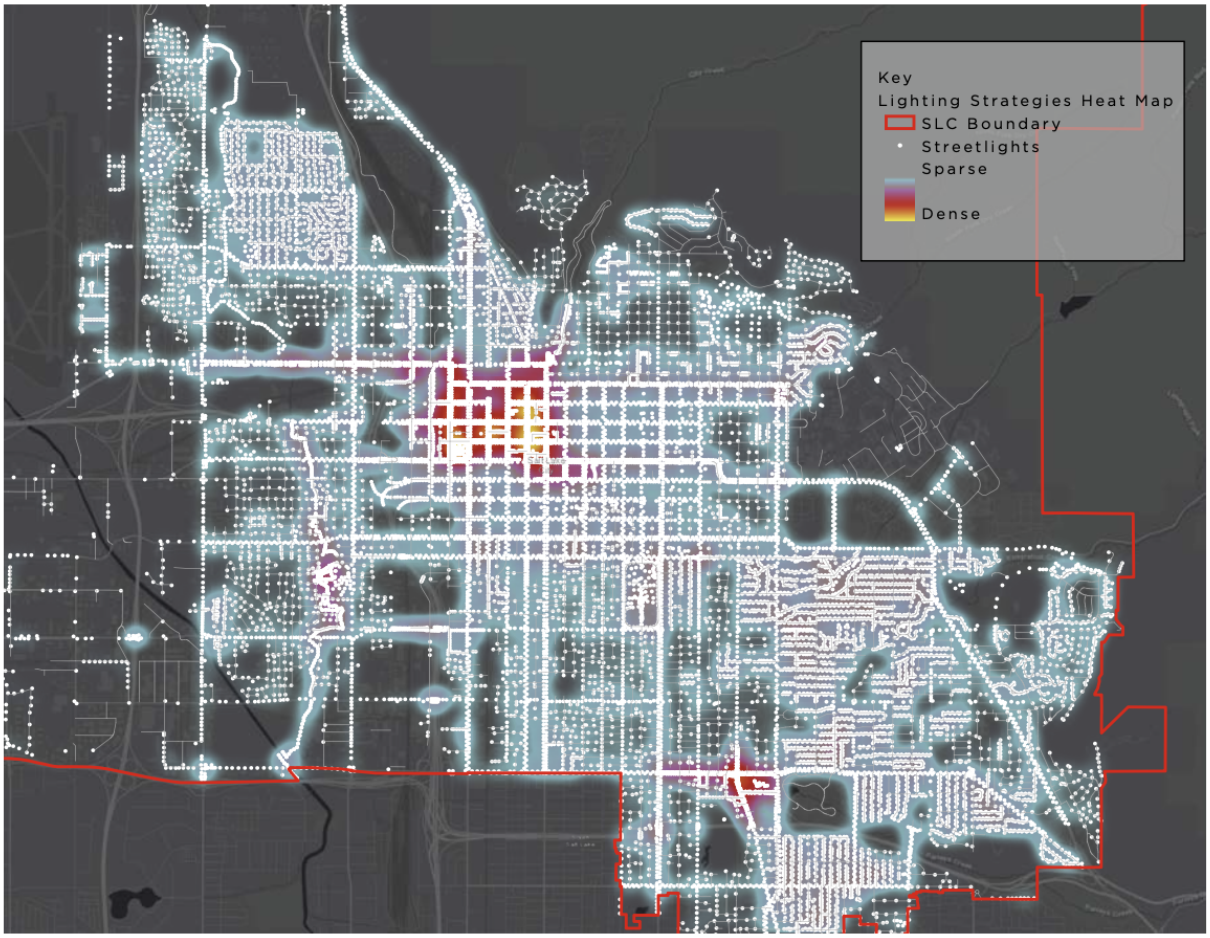


Figure 3: Street Light Density Map

APPENDIX D

TABLE 5: LIGHTING LAYOUT STRATEGY BY LAND USE

ADJACENT LAND USE	MAIN CONSIDERATIONS	ENVIRONMENTALLY PROTECTIVE ACTIONS	MAX CCT*	LIGHTING STRATEGIES
Commercial	• Diverse Land Use with High, Medium, and Low Pedestrian and Vehicle Activity During Night Hours	• Adaptive Dimming	• 3000K	• All Lighting Strategies Possible to Safely and Appropriately Light the Streets and Sidewalks.
Office Park	• Low Pedestrian Conflict at Night • Overlap with Environmentally Protected Areas	• Lower CCT • Adaptive Dimming	• 3000K	• Non-Continuous Street Lighting • Possible Non-Continuous Pedestrian Lighting
Downtown	• High and Medium Pedestrian and Vehicle Activity During Night Hours • Historic Character using Cactus Pole Lights	• Adaptive Dimming	• 3000K	• Continuous Street and Pedestrian Lighting
Industrial	• Low Pedestrian Conflict at Night • Environmental Concerns	• Lower CCT • Adaptive Dimming	• 2200K	• Street Lighting at Intersections Only
Multifamily Residential	• Pedestrian Safety • Representing the Character of the Area	• Minimizing Light Trespass • Controlling Spectrum • Adaptive Dimming	• 3000K (Arterial) • 2700K (Collector/ Local)	• Continuous and Non-Continuous Street Lighting • Continuous and Non-Continuous Pedestrian Lighting
Single Family	• Pedestrian Safety • Representing the Character of the Area	• Minimizing Light Trespass • Controlling Spectrum • Adaptive Dimming	• 3000K (Arterial) • 2700K (Collector Local)	• Continuous and Non-Continuous Street Lighting • Continuous and Non-Continuous Pedestrian Lighting
Open Space	• Environmental Concerns	• Minimizing Light Trespass • Controlling Spectrum • Adaptive Dimming	• 2200K	• Non-Continuous Street Lighting • Street Lighting at Intersections Only

**Max CCT to be 2000K in Environmentally Sensitive Areas.*

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

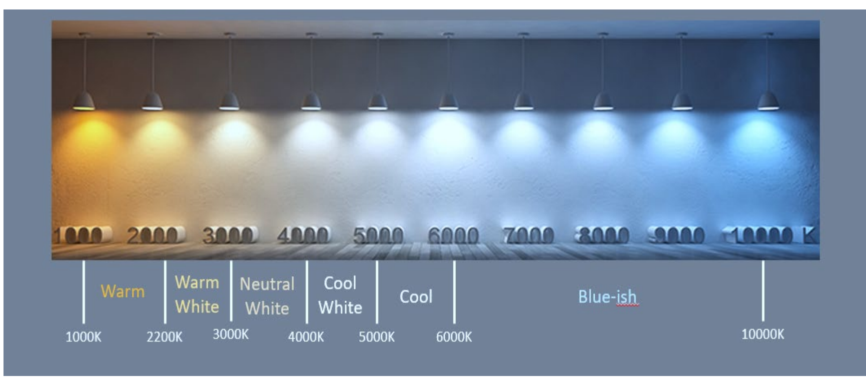
Salt Lake City Street Lighting Master Plan
Process & Issues Related to Correlated Color Temperatures (CCT)
06/16/2021

The topic of Correlated Color Temperature (CCT), which describes the perceived color of a light source, related to street lighting has become quite controversial with the transition from predominantly high pressure sodium (HPS) street lights with an amber color temperature (2200K CCT) to light emitting diode (LED) street lights, which are can vary in color temp, typically from warm white (2700K) to cool/bluish white (5000K).

Recommendation: With a complexity of various research and opinions related to the CCT of street lighting, we recommend that Salt Lake City perform a few **pilot installations that demonstrate and compare different CCTs** in a few areas throughout the city, such as Single-Family Residential, Multi-Family Residential, Commercial, and Downtown. These demonstrations will allow Salt Lake City to engage the public and stakeholder groups in the final selection of CCT that is preferred and appropriate for each area. This process should include some educational outreach to inform the public about the various issues related to CCT as described in this memo and gather data on the preferences of the public and stakeholder groups.

What is Correlated Color Temperature (CCT)?

Correlated Color Temperature (CCT) is a measure of light source color appearance as compared to an ideal blackbody radiator that is heated to a specific temperature, measured in degrees Kelvin (K). This is similar to the variation of color seen in flames of a fire or gas stove. The higher temperature flame is perceived as blue and lower temperature flame is perceived as yellow to orange.



How CCT is Addressed in the SLC Street Lighting Master Plan

The CCT of street lighting affects a few different areas of human experience and environmental impacts, including: Brightness Perception, Nighttime Visibility, Color Identification, Aesthetic Character, Personal and Cultural Preference, Human Health, Dark Skies and Behavior of Wildlife and Insects. This article from Pew Charitable Trusts, "Citing Health Concerns, Some Cities Consider Dimmer LED Streetlights" provides an overview of some of the controversial topics.

The **Salt Lake City Street Lighting Master Plan** has considered all of these perspectives by implementing a thorough Engagement Process, evaluating current research, and providing flexibility of on-going community engagement to determine the final CCT to be used in each neighborhood or Council District. This Engagement Process helped to develop the **Guideposts for this Street Lighting Master Plan, which are: Safety, Character, Responsibility and Equity**. All of the decisions and guidance within this Plan have been considered and balanced in relationship to these Guideposts. Considering the Guidepost of Responsibility, the Street Lighting Master Plan has followed the advice from the American Medical Association (AMA) and International Dark-Sky Association (IDA) for a maximum of 3000K CCT in Commercial, Retail, Civic and Downtown areas. This Master Plan goes further, by limiting the CCT in Residential areas to 2700K maximum, and near environmentally sensitive areas to 2200K maximum. By stating "maximum" CCT levels, and providing a path for on-going community engagement, **this plan allows the flexibility for each community to determine if they would prefer lower CCTs than these maximums**.

The topic of CCT related to visibility and health are currently very active areas of research, with varying conclusions which are sometimes contradictory. In general, the current body of research, and understanding of human preferences indicates the following trends, which have been categorized according to the Street Lighting Master Plan Guideposts:

- **Safety – Brightness Perception**: *Higher CCT's tend to appear brighter at night, even at lower measured light levels.* This is related to a shift in spectral sensitivity toward blue light in lower light levels experienced at night under street lighting. While this can have a positive effect on visibility, it can also have a negative effect of increased glare if not properly controlled. Early LED streetlight conversions using cool/bluish white (5000K) LEDs installations received significantly negative public reaction.

- **Safety – Nighttime Visibility**: *Higher CCT's may improve visibility at night, however, some studies are contradictory*. Some street lighting visibility studies show that higher CCT's result in improved visual detection distance[1]. Other studies show lower CCT's with improved detection distance, however, the lower CCT may result in fatigue and reduced detection distance over longer periods of time[2].

- **Safety – Color Identification**: *Color Rendering is more important than CCT for color identification*. This topic of color identification was noted as a high priority for the Police Department. Prior to LED, lower CCT light sources like high pressure sodium (HPS) (2200K) and low pressure sodium (LPS) (1800K) also had very low color rendering index (CRI), making it more difficult to accurately identify colors of objects seen under these light sources. Newer LEDs that use a phosphor-corrected amber (PC Amber) to achieve lower CCTs (1800K – 2200K) can have improved CRI that is closer to higher CCT light sources. The PC Amber light source does not yet have wide-spread use in street lighting, and has not been included in many street lighting research studies. The proposed pilot studies are an excellent opportunity for Salt Lake City to evaluate PC Amber LED against standard white-light LEDs that are based on phosphor-corrected blue LEDs.

- **Character – Aesthetics, Personal & Cultural Preference**: *CCT can evoke a wide variety of emotions or perceptions, which can vary from person to person.* The very warm amber light from streetlights with lower CCT's (1800K – 2200K) associated with the legacy light sources of LPS and HPS may be perceived as "outdated" by some, while others perceive this color as "warm" and "inviting. Higher CCT's (4000K +) are often perceived as "institutional" or "sterile", while some may perceive this as "contemporary", "clean" and "crisp". The proposed pilot studies would allow citizens and stakeholders to express their subjective opinions and allow the City to make a data-driven decision for what is appropriate in different areas.

1800K **2200K** **2700K** **3000K** **3500K** **4000K**

Warmer	---	Cooler
Private/Intimate	---	Public
Residential/Hospitality	---	Commercial/Institutional
Historic	---	Contemporary
Fuzzy/Dingy	---	Crisp/Clean
Comfortable	---	Glary

- **Responsibility – Human Health**: *Exposure to too much light at night, especially higher CCT light with more blue content, can disrupt healthy sleeping cycles, or circadian rhythms, in humans.* Light in the blue spectrum suppresses melatonin, which is needed during the day for people to wake up and be alert. Exposure to blue spectrum light at night also suppresses or delays melatonin production, resulting in sleep disruption, which can lead to increased long-term risk of some types of cancer, including breast cancer and prostate cancer. While higher CCT lighting does play a significant role in melatonin suppression, it is also important to control light levels, reduce glare, and avoid light trespass from street lighting. Total exposure to light at night, or dosage of light, is needed to understand the full impact of street lighting as compared to other light exposure from interior lighting, computer screens, TVs and light trespass from private property.

- **Responsibility – Dark Skies**: *Higher CCT light sources with more blue spectrum light contribute more to sky glow than lower CCT light sources.* The molecular composition of the Earth's atmosphere refracts, or scatters, blue spectrum light, which is why our sky looks blue. Controlling light that is distributed directly upward into the sky is critical to reducing light pollution. This Street Lighting Master Plan includes recommendations to reduce light pollution from all decorative lights, including Downtown and Sugarhouse historic lights and neighborhood pedestrian lighting, such as Rose Park. This Plan also reduces blue spectrum content, changing from 4000K CCT to 3000K, 2700K and 2200K CCTs, depending on adjacent land use.

- **Responsibility – Behavior of Wildlife and Insects**: *In general, higher CCT light sources with more blue spectrum light result in more negative effects on wildlife and insects.* All full spectrum white lights (2700 K and up) are considerably more biologically active than existing HPS lights and new PC Amber LED lights. Using fully-shielded, low glare lights is also an important factor in reducing impacts to wildlife and the ecosystem. Limiting light trespass into open space areas and critical wildlife habitats, and providing adaptive dimming schedules are also included in this Street Lighting Master Plan.

- **Equity – What is the Right Thing for each Neighborhood?**: *Engaging each community in the final decision for the type of lighting and CCT is an important part of an equitable solution.* This process should include some education on the topics included in this memo and others related to street lighting, as well as some survey and pilot demonstration to gather data on the opinions of the residents and business owners in the area. While some areas may want more light and higher CCT for safety concerns, this should be balanced with a responsible approach that incorporates all the issues of human and environmental health, especially in residential areas.

More Background Information

1. **Engagement Process**

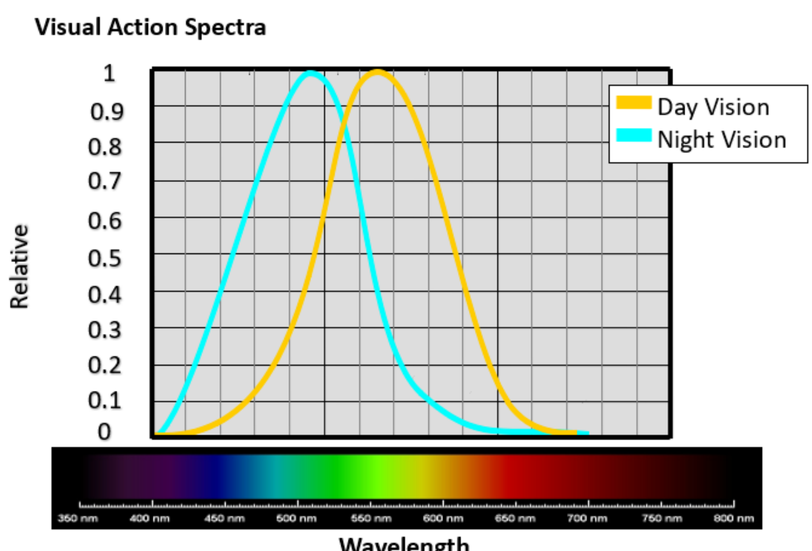
The Salt Lake City Street Lighting Masterplan was developed from a multi-level approach with a diverse set of stakeholders and community members including:

- An **Advisory Committee** which met six times and included representatives from each City Council District, Department of Public Utilities, and the Mayor's Office. The Advisory Committee provided guidance on policy issues and visioning. This group participated in site tours and surveys, visioning sessions and progress updates along the way.
- A **Technical Committee** with City representatives from Police, Fire, Sustainability, Engineering, Planning and Urban Forestry. The Technical Committee represented the interests of their departments and contributed to the vision and guiding principles. This group participated in a site tour to inform their feedback throughout the process.

The material and ideas produced from both groups was them reviewed by a **community stakeholder group** with representation from Education, Business, Transit/Multi-modal transportation, and Environmental organizations. The final draft plan includes input from both committees and feedback received during stakeholder review. Once the draft document was complete, it received initial review from the City Council and Planning Commission with a final recommendation to the City Council for adoption.

2. **Guideposts: Safety, Character, Responsibility, Equity**
    a. **Safety**
        i. **Brightness Perception**

The human eye contains two types of light activated cells in the retina, cones and rods. Cone cells require a higher light level to be activated, and are responsible for color perception, experienced during the day and under interior light levels. The rod cells are activated under lower light level conditions typically experienced at night, and provide only gray-scale visual perception. The cones are more sensitive to the yellow end of the spectrum and rods are more sensitive to the blue end of the spectrum. All lighting metrics, even for street lighting use the daytime visual sensitivity curve, yet LED light sources with more blue spectrum content, or higher CCT, appear brighter under lower light levels than lower CCT light sources. This effect is known as the Purkinje Shift. This explains why people often perceive LED street lights as "brighter" and "more glary".



Adapted from Brainard et al. Journal of Neuroscience, 2001

ii. Nighttime Visibility Research

There are multiple studies by the Virginia Tech Transportation Institute (VTTI) that study how different street lighting characteristics affect visibility. These studies measure visual detection distance of objects under different light levels and CCT's. Some studies show that higher CCT's, particularly 4000K – 4100K resulted in increased visual detection distance, even at 25% of the light level of HPS lights at 2100K[1]. Yet, the results are not consistent when comparing CCT and detection distance across multiple studies, and a more recent study showed that HPS at 2100K resulted in increased visual detection distance than 4000K LED[2].

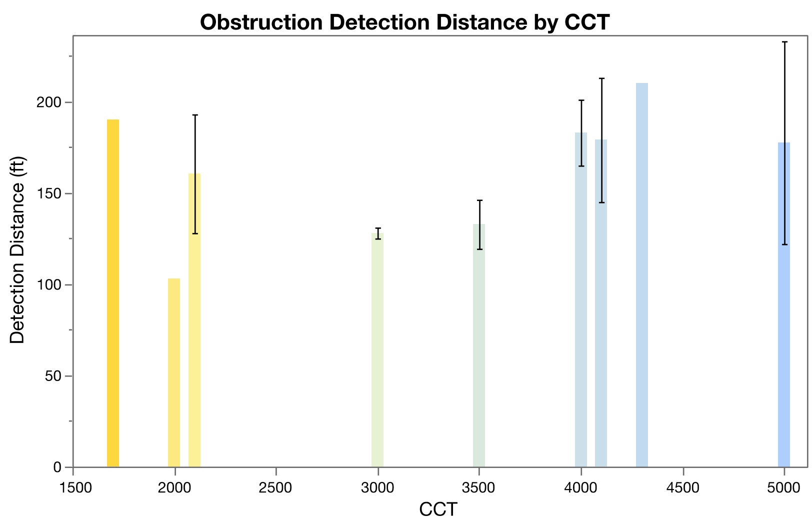


Figure summarizing studies on detection distance under different roadway lighting in Anchorage, San Jose, San Diego, and Seattle.

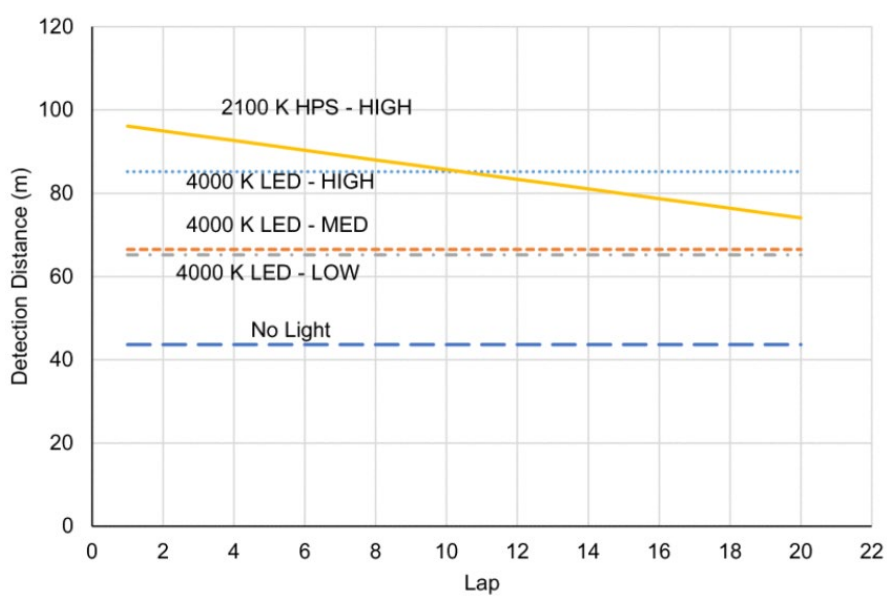
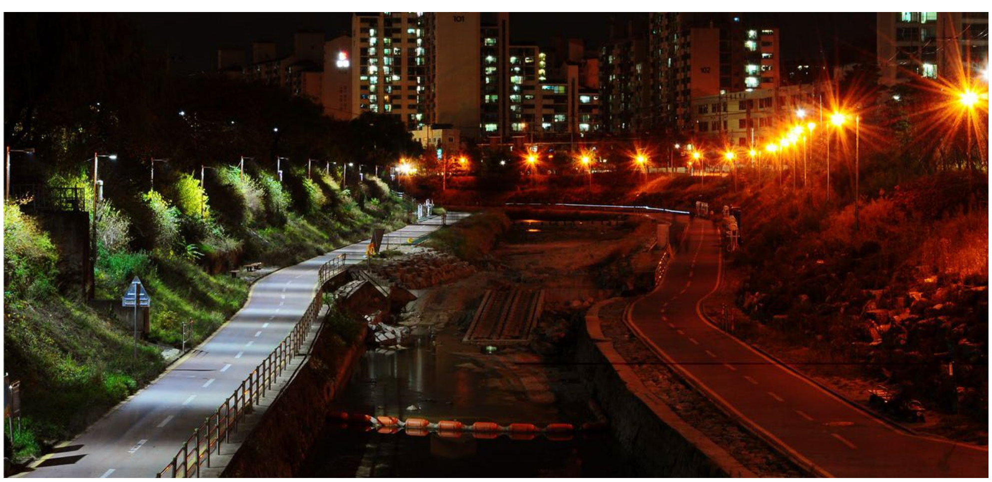


Figure showing comparison of CCT and different light levels on Detection Distance over multiple laps driving around a test roadway at Virginia Tech Transportation Institute[2].

iii. Color Identification

Accurate color identification of objects depends on the spectrum of the light source illuminating the object. This is measured as Color Rendering Index (CRI), which ranges from 0 – 100, using a broad spectrum light incandescent source as the reference. The image below shows a red car parked in front of a convenience store with two different light sources illuminating the car. The parking lot has low pressure sodium lights (CRI - 0) that have a very narrow, amber color spectrum, which distorts the red color of the car. The front of the car, near the fluorescent light (CRI - 70) emanating from the convenience store has a broader spectrum of light, which more accurately renders the red color.

LED light sources commonly used for street lighting with CCT of 2700K – 5000K typically have a CRI of 70 – 80. The most common legacy light source for street lighting was high pressure sodium (HPS) with a CCT of 2200K had a CRI of 20 – 35. The image below shows a side-by-side comparison of these light sources (LED on the left, and HPS on the right) and their resulting ability to render colors in the field of vision.



Newer PC Amber LED light sources provide 2200K and lower CCT with CRI’s ranging from 35 - 68. The higher range of this CRI is comparable to the lower range of CCT for LEDs with higher 2700K - 5000K. While most major street lighting manufacturers do not currently offer PC Amber as a standard option, most manufacturers will consider providing PC Amber as a special modification.

3. Character

a. Perception of Character and Aesthetics

Color temperature of lighting affects many different aspects of human experience. Color temperature is perceived as cooler (blue) to neutral (white) to warmer (yellow to orange), which is inverse to the temperature measurement of the ideal black body radiator (or flame temperature). Higher color temperatures are described as "cooler" and lower color temperatures are described as "warmer". Color temperature can also evoke certain emotions or perceptions such as:

1800K 2200K 2700K 3000K 3500K 4000K

Warmer	---	Cooler
Private/Intimate	---	Public
Residential/Hospitality	---	Commercial/Institutional
Historic	---	Contemporary
Fuzzy/Dingy	---	Crisp/Clean
Comfortable	---	Glary

References	1800K	2200K	2700K	3000K	3500K	4000K	5000K	6000K
In Nature	Campfire				Sunrise/Sunset	Moon		Daylight
Color Description	Orange	Amber	Warm White	Warm White	Neutral White	Cool White	Cool	Blue
Legacy Light Sources	Low Pressure Sodium (LPS)	High Pressure Sodium (HPS)	Incandescent	Halogen	Neutral White Fluorescent	Cool White Fluorescent		Daylight Fluorescent (Limited Use)
Interior Lighting	Limited Use	Dimmed Hospitality	Residential / Hospitality	Residential / Hospitality	Office	Office / Healthcare	Office / Healthcare (Limited Use)	
Exterior Lighting	Near Astronomic Observatories	Street Lighting before LED		Higher End Pedestian Lighting			Early LED Street Lighting Installations	

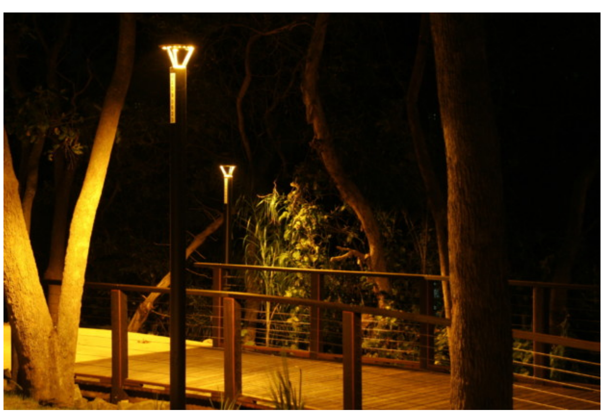


Figure 1. Example of PC Amber used in an environmentally sensitive area. https://adlt.com.au/wp-content/uploads/2014/02/IMG_7110-620x413.jpg

Figure 2. Example of 2200 K LED used for environmental and aesthetic sensitivity.
https://www.atpiluminacion.com/files/actualidad/201223_Yamaguchi/atp-iluminacion-yamaguchi-2@2x.png

Figure 3. Example of 2700 K LEDs in the field.

Figure 4. Example of 3000 K LEDs in the field. https://www.clantonassociates.com/our-projects/16th-street-mall

Responsibility (Longcore)

b. CCT / Spectrum & Human Health

Human circadian rhythms can be influenced by exposure to light at night. The mechanism is presumed to be the suppression of melatonin production. Melatonin is a naturally occurring hormone that is produced by humans and most organisms during darkness and it plays central roles in regulating human daily rhythms across all aspects of human physiology. It is also “oncostatic”, meaning that it keeps cancer tumors from growing. Because exposure to too much light at night suppresses melatonin, unnatural light exposure has been identified as a risk factor for certain cancers, including breast and prostate cancer. Suppression of melatonin varies depending on the wavelengths of light, with a peak sensitivity in the light blue. Daylight, with a color temperature of 6500 K, is very effective at suppressing melatonin production (Figure 5).

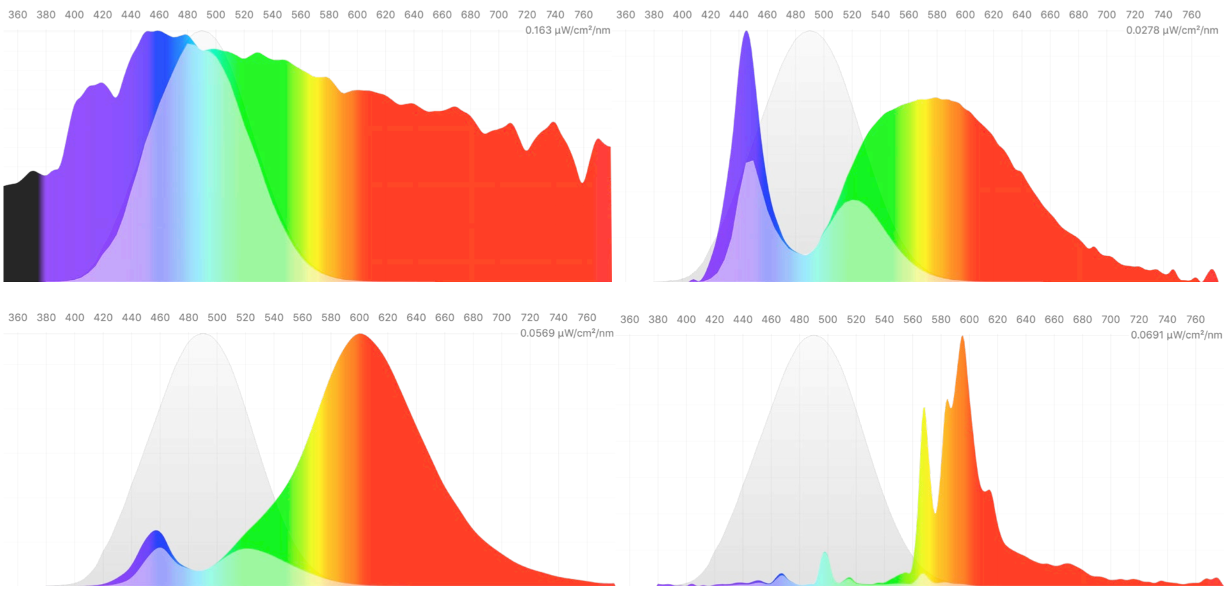


Figure 5. Spectral power of daylight (colors) with the overlap with human melatonin suppression sensitivity (lighter colors). Melatonin sensitivity curve is in the background in gray. Upper left: Daylight (D65), Upper right: 4200 K LED, Lower left: 2200 K LED, Lower right: 1900K High Pressure Sodium. Source: fluxometer.com

The relative power of lights to suppress melatonin can be calculated, and it decreases with color temperature for standard light sources (Figure 3).

Few studies connect color temperature with health outcomes in the epidemiological literature, perhaps because the technology to do such studies is only recently becoming available. A study of breast and prostate cancer in Spain published in 2018 provides initial information, which is consistent with greater effects being associated with higher color temperatures. In this study, greater blue light outdoors at residences of cancer patients compared with those of controls was associated with a 47% increased risk of breast cancer and a doubling in prostate cancer risk[3]. In contrast, outdoor lighting alone (of all colors) was not associated with increased risk. The study also accounted for light experienced in the sleeping environment, with a significantly greater risk of prostate cancer for those sleeping in a “quite illuminated” bedroom, but no statistically significant result for breast cancer[3].

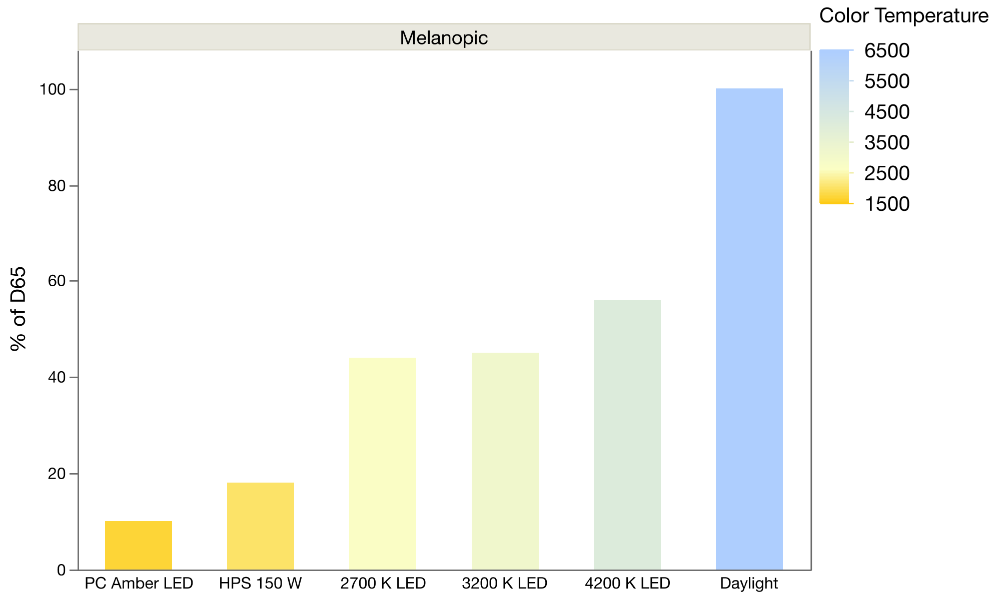


Figure 3. Relative sensitivity of human circadian system, as measured by melatonin suppression, for typical LED light sources and High Pressure Sodium, compared with an equal brightness of daylight.

Scientists who are skeptical about the potential for outdoor to affect human health point to the intensity thresholds for melatonin suppression. Based on models of human physiology, they demonstrate that melatonin suppression is likely to be very small or not measurable below approximately 5 lux[4]. Since outdoor lighting rarely reaches these levels within dwellings, the impact is presumed to be minimal, regardless of color temperature. This argument, however, does not extend to exposures outdoors at night and illumination under street lighting often exceeds 5 lux.

A precautionary approach to color temperature for human circadian health relative to outdoor lighting would be to favor the use of lower color temperature lighting (Figure 3), which then would be balanced against other guideposts.

c. CCT / Spectrum & Critical Wildlife Habitat
   i. Tracy Aviary

Color temperature is one factor that influences the degree to which light at night affects wildlife. Depending on the group of organisms, color may be able to reduce or increase effects a little or a lot. One group where color is relatively more important is insects, which are, in general, more attracted to blue, violet, and ultraviolet than yellows and reds. There are exceptions to this pattern, but studies of insect attraction to different color temperatures of LED find that lower color temperatures attract fewer insects. This relationship has been quantified and can be used to compare attraction of specific options for street lighting (Figure 4). For nearly all organisms investigated, lower color temperatures are assessed to have reduce impacts. The difference between 2700 K and 3000 K tends to be small, and all full spectrum white lights (2700 K and up) are considerably more biologically active than existing HPS lights.

There is no evidence that color temperature is a driving force in attraction and mortality of migratory birds, however. Light visible from above affects the distribution of migratory birds[5, 6], but the satellite used for these studies does not distinguish between colors of light and in fact does not measure blue and violet light at all. The recommended approach to reduce impacts on migratory birds from roadway lighting is to fully shield lights to eliminate upward glare and to only use the amount of light necessary so that the reflected light is kept to a minimum. Current efforts to reduce bird mortality in Salt Lake City by the Tracy Aviary focus on voluntary efforts by building owners to shut off interior lights during migration. The amount of lighted window area on buildings correlates with bird collisions[7]. The project team discussed these issues with Ms. Cooper Farr of the Tracy Aviary during the development of the Master Plan.

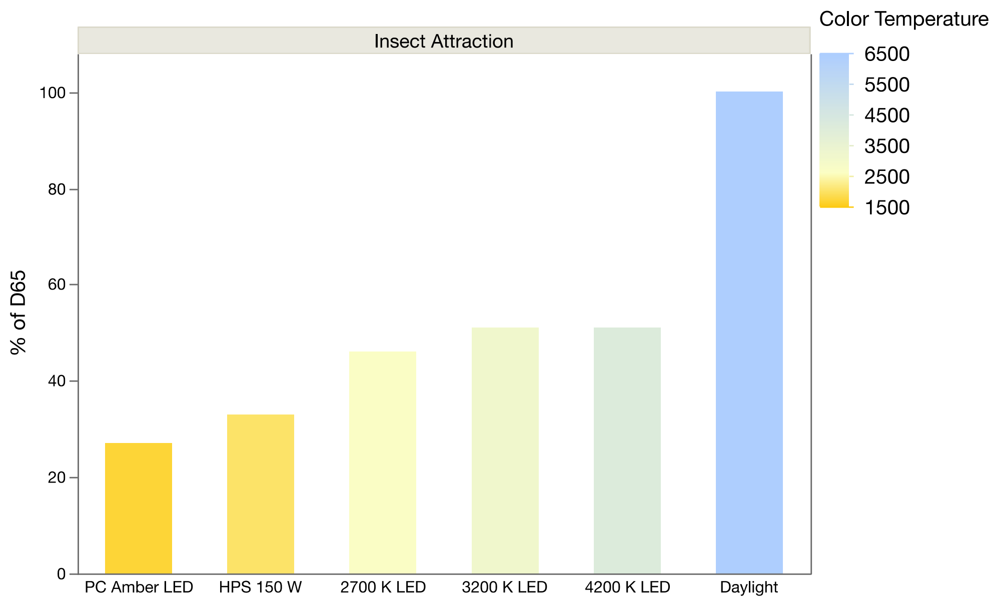


Figure 4. Relative attractiveness of different LEDs and High Pressure Sodium to insects, as quantified Longcore et al.[8] from an insect attraction curve developed by Donners et al.[9]

d. CCT / Spectrum & Dark Skies

We followed the work of the Department of Energy with respect to the effect of different color temperatures on light pollution for astronomical observation[10]. The DOE study modeled the effects of different combinations of spectrum, uplight, and intensity under different weather conditions, human vision adaptation levels, and distance from the lights. These results compare high-pressure sodium as the baseline, with PC Amber LED (1872 K), and 2700–6100 K LEDs. When compared on an equal basis for other factors (same uplight and intensity), only the PC Amber produced roughly equivalent light pollution compared with HPS and all full-spectrum LEDs produced significantly more light pollution, especially when considering human night vision. This difference is shown for a range of LEDs and HPS using the "starlight index"[11] (Figure 5). When both HPS and LEDs were assumed to have 0% uplight and the LEDs were set at half the intensity of the LEDs, then LEDs with CCT < 3000 K were comparable to or produced less light pollution than HPS. Results were similar with HPS at 2% uplight and LEDs at 0% uplight and 50% intensity.

The take-home message of this research for the Salt Lake City street lighting master plan is that for LED lamps lights to reduce light pollution compared with the previously common HPS lamps, they must be 0% uplight, 50% less bright, and with a CCT of no greater than 3000 K. The minimum impact on light pollution could be achieved with PC Amber or comparable filtered LEDs that produce a similar CCT as HPS (~ 1800 K).

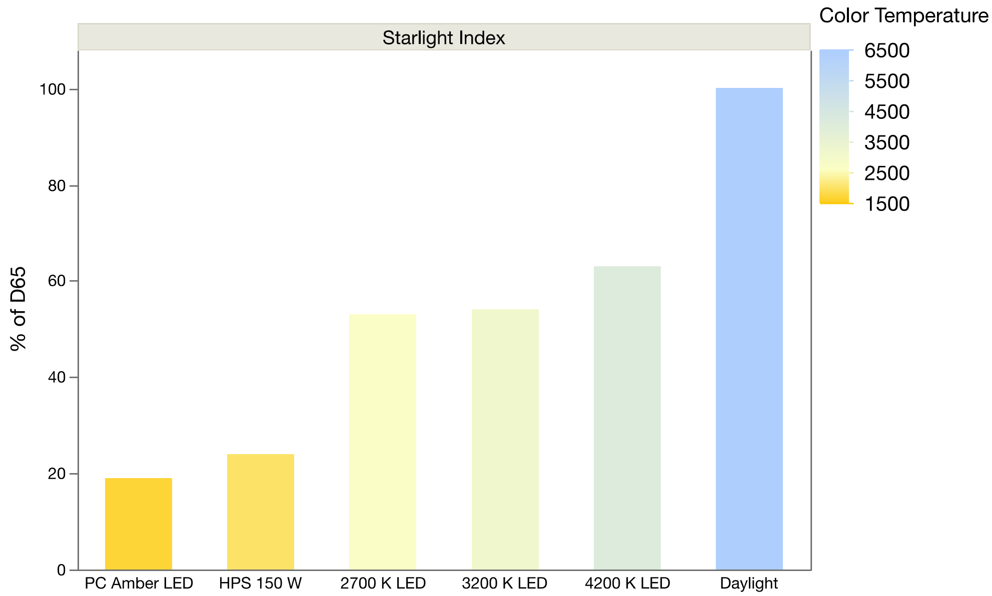


Figure 5. Relative impact of LEDs and HPS compared with a source similar to daylight, using the starlight index[9]. 2700–3000 K LEDs are similar in impact to HPS if they are operated with half of the lumen output of the HPS.

4. Equity

This Street Lighting Master Plan strives to provide an equitable approach to the recommendations and establishment of priorities for implementation. This approach identifies areas that are currently underserved with street and pedestrian lighting. Some of these areas have expressed concerns of safety, and would prefer to have more lighting installed in their neighborhood. Other areas, that currently darker and have few street or pedestrian lights, have expressed concerns about dark skies and light trespass, and would prefer to no additional lighting it their neighborhood. With these disparate perceptions, this Street Lighting Master Plan encourages on-going community engagement before implementing any street lighting projects to determine what lighting strategies the community would prefer.

During this on-going public engagement process, it is important to include some public education about the issues involved with guideposts, including CCT issues that are discussed in this memo. It is also as important to implement pilot demonstrations that allow citizens to see and experience the lighting options, including CCT and dimming, to gather data to make a fully informed decision on the final street and pedestrian lighting strategies to implement in any neighborhood.

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Report 968. Transportation Research Board, Washington, D.C.
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[4] Grubisic, M., et al., Light pollution, circadian photoreception, and melatonin in vertebrates. Sustainability, 2019. 11(22): p. 6400.
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[6] McLaren, J.D., et al., Artificial light at night confounds broad-scale habitat use by migrating birds. Ecology Letters, 2018. 21(3): p. 356–364.
[7] Parkins, K.L., S.B. Elbin, and E. Barnes, Light, glass, and bird–building collisions in an urban park. Northeastern Naturalist, 2015. 22(1): p. 84–94.
[8] Longcore, T., et al., Rapid assessment of lamp spectrum to quantify ecological effects of light at night. Journal of Experimental Zoology Part A: Ecological and Integrative Physiology, 2018. 329(8-9): p. 511–521.
[9] Donners, M., et al., Colors of attraction: modeling insect flight to light behavior. Journal of Experimental Zoology Part A: Ecological and Integrative Physiology, 2018. 329(8-9): p. 434–440.
[10] Kinzey, B., et al., An investigation of LED street lighting's impact on sky glow. 2017, U.S. Department of Energy (Contract DE-AC05-76RL01830): Richland, Washington.
[11] Aubé, M., J. Roby, and M. Kocifaj, Evaluating potential spectral impacts of various artificial lights on melatonin suppression, photosynthesis, and star visibility. PLoS ONE, 2013. 8(7): p. e67798.

SALT LAKE CITY PLANNING COMMISSION MEETING
This meeting was held electronically pursuant to the
Salt Lake City Emergency Proclamation
Wednesday, April 14, 2021

A roll is being kept of all who attended the Planning Commission Meeting. The meeting was called to order at approximately 5:30 pm. Audio recordings of the Planning Commission meetings are retained for a period. These minutes are a summary of the meeting. For complete commentary and presentation of the meeting, please visit https://www.youtube.com/c/SLCLiveMeetings.

Present for the Planning Commission meeting were: Vice Chairperson, Amy Barry; Commissioners; Maurine Bachman, Adrienne Bell, Carolynn Hoskins, Jon Lee, Matt Lyon, Andres Paredes, Sara Urquhart, and Crystal Young-Otterstrom. Chairperson Brenda Scheer was excused.

Planning Staff members present at the meeting were: Wayne Mills, Planning Manager; Molly Robinson, Planning Manager; Paul Nielson, Attorney; David Gellner, Principal Planner; Krissy Gilmore, Principal Planner; Aaron Barlow, Principal Planner; Marlene Rankins, Administrative Assistant; and Aubrey Clark, Administrative Assistant.

Vice Chairperson, Amy Barry read the Salt Lake City emergency proclamation.

REPORT OF THE CHAIR AND VICE CHAIR
Chairperson Scheer was not present.

Vice Chairperson Barry stated she had nothing to report.

REPORT OF THE DIRECTOR
Wayne Mills, Planning Manager, provided the public with instructions on how to participate during the meeting. He also provided the commission with information regarding how permits and zoning functions in the City.

CONSENT AGENDA

Red Rock Brewery Brewhouse at approximately 426 West 400 North - Conditional Use and Conditional Building and Site Design Review Time Extension Requests - MJSA Architects representing 200 West Holding, LC the property owner, is requesting that the Planning Commission grant a one-year time extension on the Conditional Use and Conditional Building and Site Design (CBSDR) approvals for a brewery at the above listed address. The Commission originally granted Conditional Use and CBSDR approval for this project on April 24, 2019. A one-year extension to the Conditional Use approval was previously granted on April 22, 2020. This request would extend both approvals to expire on April 24, 2022. The project is located within the TSA-UC-T (Transit Station Area Urban Center Transition) zoning district within Council District 3, represented by Chris Warton. (Staff contact: David J. Gellner at (385-226-3860 or david.gellner@slcgov.com) **Case numbers PLNPCM2018-01008 & PLNPCM2019-00255**

APPROVAL OF THE MARCH 24, 2021, MEETING MINUTES.

MOTION
Commissioner Lyon moved to approve the consent agenda. Commissioner Bell seconded the motion. Commissioners; Bachman, Bell, Hoskins, Lee, Paredes, Urquhart, Young-Otterstrom, and Lyon voted "Aye". The motion passed unanimously.

PUBLIC HEARINGS

Bookbinder Studios on 2nd West Design Review at approximately 422 South 200 West - A request by Scott Harwood, representing OZ Opportunity Fund LLC, is requesting Design Review approval to develop a 7-story, 83'-1" tall residential structure to be located on two contiguous parcels located at 418 S 200 W and 422 S 200 W. The proposed building will encompass 115 studio and one-bedroom units. The building will have two structured parking levels with 58 parking stalls and five levels of apartment units above. The applicant is requesting Design Review approval to allow for additional building height and modification to the required building entrances. The project site is located in the D-2 (Downtown Support) zoning district and is located within Council District 4, represented by Ana Valdemoros (Staff contact: Krissy Gilmore at (801) 535-7780 or kristina.gilmore@slcgov.com) **Case number PLNPCM2021-00035**

Krissy Gilmore, Principal Planner, reviewed the petition as outlined in the Staff Report (located in the case file). She stated Staff recommended that the Planning Commission approve the request with the conditions listed in the staff report.

The Commission and Staff discussed the following:

- Clarification on number of parking spaces provided

Scott Harwood, Eric Hansen, and Jonathan Kland, applicants, provided a presentation with further details.

The Commission, Staff and Applicant discussed the following:

- Clarification on entrance layout
- Whether the entrance is visible from the street or the parking lot

PUBLIC HEARING
Vice Chairperson Barry opened the Public Hearing;

Lisa Hazel – Raised concern with energy efficiency and would like to see bike parking.

Cindy Cromer – Stated that in the East downtown, a building of this height used to be an allowed use. She also stated she thinks it's time that something is done about the fact that the planners are spending time on a request like this, where units that will be available and are modestly priced have been delayed arriving in the market place by the amount of time that the petition has been in the Planning Department.

Seeing no one else wished to speak; Vice Chairperson Barry closed the Public Hearing.

The applicant addressed the public comments.

The commission and applicant discussed the following:

- Clarification on height of structure behind the proposal
- Clarification on whether the City will be undertaking mandatory zoning amendments with the result of legislative changes
- Affordable Housing Overlay zone
- Design Review ordinance modifications and when a proposal for height should go before the Commission

MOTION
Lyon Based on the analysis and findings listed in the staff report, information presented, and the input received during the public hearing, I move that the Planning Commission approve the Design Review request (PLNPCM2021-00035) for the project located at approximately 422 S 200 W with the conditions listed in the staff report.

Commissioner Urquhart seconded the motion. Commissioners Bachman, Bell, Hoskins, Lee, Paredes, Urquhart, Young-Otterstrom, and Lyon voted "Aye". The motion passed unanimously.

2020 Salt Lake City Street Light Master Plan - Representatives from the Department of Public Utilities of the City will provide an overview of the 2020 Salt Lake City Street Light Master Plan (Plan). Major changes in the 2020 Plan from the 2006 Plan include a systematic approach for choosing lighting strategies of public ways based on adjacent land use, pedestrian activity, and street typology. The 2020 City Street Light Master Plan includes all areas of the City and will impact all City Council districts. (Staff Contact: David Pearson, Streetlight Program Manager at (801) 483-6738 or david.Pearson@slcgov.com; or Marian Rice, Deputy Director at (801) 483-6765 or marian.rice@slcgov.com)

Aaron Barlow, Principal Planner, introduced Marian Rice, Deputy Director of Salt Lake City Department of Public Services, and Jesse Stewart Salt Lake City Department of Public Services.

The following participants were also available for questions:
- Laura Briefer; SLCDPU
- Jesse Stewart; SLCDPU
- Marian Rice; SLCDPU
- David Pearson; SLCDPU
- Dane Sanders, Clanton & Associates;
- Annaka Egan, GSBS;
- Jesse Allen, GSBS;
- Travis Longcore;

Jesse Stewart, provided a presentation with details regarding the proposal.

The Commission and Staff discussed the following:
- Clarification on how neighborhood byway is defined
- Process when a resident request a light on their street
- Clarification on whether there is a standard number of lights on a street

PUBLIC HEARING
Vice Chairperson Barry opened the Public Hearing;

Lisa Hazel – Stated her opposition of the request.

Judi Short – Provided an email comment that was read into the record requesting to know the type of public engagement was performed.

Dave Iltis – Stated his opposition of the request in its current form.

Seeing no one else wished to speak; Vice Chairperson Barry closed the Public Hearing.

Dane Sanders addressed the public comments and concerns.

The Commission and Staff discussed the following:

- Clarification on why the highest amount of kelvin was chosen

MOTION

Commissioner Lyon stated, based on the findings, analysis, testimony and plan presented, I move that the Planning Commission forward a positive recommendation to the City Council to adopt the 2020 Street Lights Master Plan and the accompanying Technical Guidance and Implementation document. With a recommendation to the City Council:

1. **To further explore the warmness of the light and the kelvin temperatures and further understand that fully.**

Commissioner Young-Otterstrom seconded the motion. Commissioners Bachman, Bell, Hoskins, Lee, Paredes, Urquhart, Young-Otterstrom and Lyon voted "Aye". The motion passed unanimously.

The meeting adjourned at approximately 7:05 pm.

ERIN MENDENHALL
MAYOR

LAURA BRIEFER, DIRECTOR
DEPARTMENT OF PUBLIC UTILITIES

CITY COUNCIL TRANSMITTAL

Lisa Shaffer (Jan 13, 2021 13:43 MST)
Lisa Shaffer, Chief Administrative Officer

Date Received: 10/14/2020
Date sent to Council: 1/13/2021

TO: Salt Lake City Council
Amy Fowler, Chair

DATE: 10-14-2020

FROM: Laura Briefer, Director, Department of Public Utilities

SUBJECT: 2020 Salt Lake City Street Light Master Plan

STAFF CONTACTS: Jesse Stewart, Deputy Director, jesse.stewart@slcgov.com;
Jason Brown, PE, Chief Engineer, jason.brown@slcgov.com;
David Pearson, PE, Street Lighting Manager, david.pearson@slcgov.com;
Jeff Snelling, PE, Senior Engineer, jeff.snelling@slcgov.com

DOCUMENT TYPE: Ordinance

RECOMMENDATION: Adoption of the 2020 Salt Lake City Street Lighting Master Plan.

BUDGET IMPACT: The adoption of the 2020 Salt Lake City Street Lighting Master Plan does not have a budget impact for this fiscal year. The Street Lighting Utility budget is prepared annually, and implementation of this proposed plan will be reflected in future annual budgets. Due to certain recommended changes related to pedestrian lighting and safety, it is anticipated that Public Utilities will need to prepare an updated capital improvement program and financial strategy for the Street Lighting Enterprise Fund to implement the Plan beginning in Fiscal Year 2022.

BACKGROUND/DISCUSSION:

Salt Lake City was the 5th City in the United States to have streetlights. The City's first systematic plan for installing streetlights was adopted in 1908. The most recent street lighting plan was completed in 2006. In 2013, the management of the streetlight system was transferred from the Transportation Division to the Department of Public Utilities. This transfer included changing the funding source for the operation, maintenance and capital improvements of the system from the General Fund and Special Assessment Areas (SAA's) to a newly created street lighting enterprise fund.

Currently Public Utilities maintains over 15,500 streetlights within Salt Lake City boundaries. The Street Lighting Enterprise Fund was primarily developed to maintain existing lighting and upgrade fixtures to newer technology LED. First generation LED lights installed had few options regarding lumen output (measure of light output and brightness) and color temperature (whiteness of the light). The City's practice was to replace the older fixtures with LED fixtures at the same lumen output using a 4,000-Kelvin temperature, which at the time was the industry standard. These new LED fixtures had the same measurable light output but were perceived as a brighter light. During the first few years of conversion to the new LED fixtures mainly within industrial, commercial and higher density residential areas, Public Utilities received more positive feedback than negative. When installation began in the residential neighborhoods, there were more complaints. Residents were not pleased with the brightness of the lights as well as the white light emitted. The City is also proactively working on various streets projects, community improvement projects, pedestrian and bicycle friendly projects, and issues related to crime. Street lighting has a role to play in all of these endeavors.

2020 Street Lighting Master Plan Development and Content

In 2018, Public Utilities began the process of updating the Streetlighting Master Plan (Plan). This planning effort includes a review and update of policies related to the system, engagement of stakeholders in the planning process and design guidance for the City's street light system.

Public Utilities partnered with GSBS Consulting and Clanton & Associates to develop the Plan. This Plan provides design guidance for improving street and pedestrian lighting that will create a quality nighttime visual experience while being more energy efficient. Four guideposts, developed by stakeholder committees, that include Safety, Character, Responsibility, and Equity, drive the Plan's policies. The Plan also draws on bodies of knowledge throughout the world regarding advancements in the technology and science of how we can light our public ways.

The 2020 Street Lighting Master Plan incorporates two volumes, including the Master Plan itself and Technical Guidance and Implementation guide. Both are attached to this transmittal, as well as the Executive Summary for the Master Plan. Primary components of the Plan include:

- System Background
- System Evaluation
- Plan Guideposts
- Street Lighting Basics Overview
- Process for Evaluating the Lighted Environment
- Comprehensive Improvements
- Minimal Improvements
- Lighting Controls and Adaptive Dimming Strategies
- Lighting Calculations
- Appendices
    - Lighting Terms
    - Meeting Notes
    - Existing Conditions Report
    - Nocturnal Infrastructure for Ecological Health (report)
    - Luminaire Submittal Form

If approved, the 2020 Street Lighting Master Plan would implement the following major policy statements for the City:

1) Street lighting will enhance safety through the implementation of industry recognized standards.
2) Street lighting standards will include allowances to encourage dimming strategies relating to pedestrian activity, wildlife, and dark skies lighting.
3) Street lighting will minimize the obtrusive effects of light at night resulting from light trespass, light pollution, and glare through the selection and placement of appropriate poles, fixtures, light type, and light levels.
4) Provide pedestrian lighting in accordance with neighborhood plans and in accordance with the typologies of this Plan.
5) Provide street and pedestrian lighting that minimizes impacts to sensitive wildlife species.
6) Select fixture types to provide dark skies protection.
7) Implementation based on neighborhood and community input to determine pole, fixture type, maximum and minimum light level, and the implementation of adaptive dimming applications when appropriate.

Funding and prioritization are the key drivers in implementation of the polices, standards, and strategies in the Plan. Implementation recommendations outlined in the Plan are as follows:

1) **Priority One**
    a. Neighborhoods currently underserved for street and/or pedestrian lighting based on adjacent land uses
    b. High conflict areas including school zones, bus stops, transit stations, and neighborhood byways.
2) **Priority Two**
    a. Areas with non-compliant existing street lighting.

3) **Ongoing**
    a. Replacement of lamps with LED luminaires on regular maintenance schedule as appropriate.
    b. Replacement of non-compliant street lighting in areas of ecological sensitivity.
    c. Installation of dimming capability.
    d. New development or redevelopment proposals.

4) **Step One**
    a. Identify high conflict areas in the City
    b. Review the current lighting map to identify underserved neighborhoods.
    c. Respond to requests from community or neighborhoods for lighting changes
5) **Step Two**
    a. Contact community and neighborhood representatives to identify priorities and review options according the matrix developed in the Plan.
    b. Identify the community preferred option.
6) **Step Three**
    a. Estimate cost of preferred option.
    b. Seek funding approval/develop financial strategy
7) **Step Four**
    a. Design, schedule, and implement the preferred option.

If the Plan is adopted, it will reflect public feedback and the City's street lighting system will be better incorporated into City livability and development goals. Major changes in the 2020 Plan from the 2006 Plan include a systematic approach for choosing lighting strategies of public ways based on adjacent land use, pedestrian activity, and street typology. Procedures for determining pedestrian lighting are included, as are lighting procedures for environmentally sensitive areas. Because of this, the current base street lighting standard will likely change depending on the land use, pedestrian activity, and street typology. It is anticipated that Public Utilities will need to prepare an updated capital improvement program and schedule for the street lighting system if this Plan is adopted, along with an updated evaluation of street lighting rates, rate structure and financial strategies for capital improvements.

PUBLIC PROCESS:

Public Utilities consistently receives feedback regarding the current lighting system, both positive and negative. A major driver of the 2020 Street Lighting Master Plan includes this public feedback. For instance, Public Utilities has received feedback regarding the performance of LED fixtures, public safety, environment, and equity.

As part of the Plan effort, three groups were formed to advise in the development of the Plan. The first group, the Advisory Committee, consisted of representatives from each City Council District recommended by City Councilmembers or Council staff. Advisory Committee members were asked to provide input on lighting in their specific district and in common areas of the City. Throughout the course of developing the Plan this committee helped in evaluating the existing system and provided guidance pertaining to the Plan's scope and reach.

A second group formed as a Technical Committee consisting of staff from City Departments and Divisions who hold a direct interest in the street lighting program. Technical Committee members include representatives from Salt Lake City Police Department, Fire Department, Sustainability Department, Engineering Division, Planning Division, and the Urban Forestry Division. Technical Committee members provided input based on their unique responsibilities with respect to how streetlighting influenced their tasks. This committee provided direction in how lighting design criteria could assist in meeting the City's goals and more specifically, helping to accomplish their Department's individual responsibilities.

The third group was formed from stakeholders in the community including representatives from agencies and groups in the transportation, education, environmental, and business sectors who have a vested interest in Salt Lake City. The primary purpose of this group was to provide input as the Plan progressed. This provided a level of transparency and allowed for feedback to ensure the Plan had a solid foundation to address the multiple values of a comprehensive lighting system.

Public Utilities and the GSBS Consulting team met with the Advisory and Technical Committees to help frame the vision and goals of the Plan. The committees were encouraged to offer their opinion on existing lighting conditions throughout the City and what improvements could be made. These Committees toured 17 sites throughout the City with varied lighting characteristics and land use. At each of these sites committee members were asked several questions to gauge their opinion on the existing lighting conditions. The GSBS Consulting team also took light measurements at each of these locations to compare with current industry lighting standards. Using the data collected from the measured light readings and input from the committees, GSBS created an Existing Lighting Conditions report. This report summarized current lighting conditions to assist with developing design criteria and a future implementation plan using the guideposts detailed in the Plan.

Meetings and Formal Engagement:

- November 5, 2018: Street Lighting Site Tour and Surveys – Advisory and Technical Committees
- April 3, 2019: Street Lighting 101 – Advisory Committee
- April 25, 2019: Visioning Session – Advisory Committee
- April 26, 2019 – Technical Committee
- May 24, 2019: City Council and Mayor's Office Briefing
- July 29 and 30, 2019: Stakeholder Update
- April 2019 – November 2019: Public Street Lighting Survey, 160 respondents
- January 8, 2020: Progress Update – Advisory Committee
- October 22nd, 2020: Public Utilities Advisory Committee (planned)

Enclosures:
Draft Ordinance Adopting the 2020 Street Lighting Master Plan
2020 Street Lighting Master Plan Executive Summary
2020 Street Lighting Master Plan Volume 1 – Master Plan (June 2020)
2020 Street Lighting Master Plan Volume 2 – Technical Guidance and Implementation (June 2020)

SALT LAKE CITY ORDINANCE
No. _____ of 2020

(Adopting the 2020 Street Lighting Master Plan)

WHEREAS, the Salt Lake City Department of Public Utilities (Public Utilities) manages Salt Lake City's street lighting system as a separate enterprise of the City.

WHEREAS, Public Utilities has been managing the street lighting system pursuant to the City's 2006 Street Light Master Plan.

WHEREAS, Public Utilities developed a new 2020 Street Lighting Master Plan in order to be responsive and proactive through a systematic approach to address community values associated with public safety, environmental protection, and community character.

WHEREAS, community engagement was determined to be of utmost importance in developing a new Street Lighting Master Plan and Public Utilities formed three community groups to advise in the development of the Plan. The groups were called: 1) The Advisory Committee, consisting of representatives from each Council District, to provide input on lighting in their specific district and in common areas of the City; 2) The Technical Committee, consisting of staff from select City Departments and Divisions, to provide direction in how lighting design criteria could assist in meeting the City's goals and more specifically, helping to accomplish their Department's individual responsibilities; and 3) The Stakeholders Committee, consisting of community representatives from agencies and groups in the transportation, education, environmental, and business sectors, to provide overall input as the plan progressed.

WHEREAS, Public Utilities and its consultants worked with the three Committees to develop guiding principles, vision and goals of the new Master Plan.

WHEREAS, the 2020 Street Lighting Master Plan includes new lighting design criteria and implementation recommendations to better address public values associated with the City's street lighting system;

WHEREAS, at its October 22, 2020 meeting, the Public Utilities Advisory Committee voted in favor of forwarding a positive recommendation to the Mayor and City Council on adopting the Master Plan; and

WHEREAS, after a hearing before the City Council, the City Council has determined that adopting this ordinance is in the best interest of the City.

NOW, THEREFORE, be it ordained by the City Council of Salt Lake City, Utah:

SECTION 1. Adopting the Street Lighting Master Plan. That the 2020 Street Lighting Master Plan is hereby adopted to read and appear as provided in Exhibit "A" attached hereto.

SECTION 2. Effective Date. This ordinance shall become effective on the date of its first publication.

Passed by the City Council of Salt Lake City, Utah, this ______ day of ______________, 2020.

____
CHAIRPERSON

ATTEST AND COUNTERSIGN:

____
CITY RECORDER

Transmitted to Mayor on ______________________.

Mayor's Action: _______Approved. _______Vetoed.

____
MAYOR

____
CITY RECORDER

APPROVED AS TO FORM
Salt Lake City Attorney's Office
Date: Jan 13, 2021
By: ERV
E. Russell Vetter, *Senior City Attorney*

(SEAL)

Bill No. ________ of 2020.
Published: ______________.

EXHIBIT “A”

2020 Street Lighting Master Plan

SALT LAKE CITY, UT

Street Lighting Master Plan

VOLUME 1 - MASTER PLAN

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

GSBS CONSULTING

SALT LAKE CITY

JUNE 2020

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INTRODUCTION TO THE PLANNING PROCESS

The 2020 Street Lighting Master Plan was developed with the input and guidance of two committees and reviewed by a Stakeholders group. The Advisory Committee included representatives from:

- Each City Council District
- Department of Public Utilities
- Mayor's Office

The Advisory Committee met six times during the process to provide guidance on policy issues:

- Street Lighting Site Tour & Surveys (November 5, 2018)
- Street Lighting 101 (April 3, 2019)
- Visioning Session (April 25, 2019)
- Council & Mayor's Office Briefing (May 24, 2019)
- Stakeholder Update (July 30, 2019)
- 50% Progress Update (January 8, 2020)

The Advisory Committee created a list of lighting concerns and priorities for each district across the City as well as provided guidance on the City's street lighting vision and guideposts. Notes from their meetings are found in the appendix.

The second committee was the Technical Committee with representatives from the following City departments:

- Police
- Fire
- Sustainability
- Engineering
- Planning
- Urban Forestry

Technical Committee members represented the interests of their departments in the master planning process. They also participated in the street lighting site tour. Technical Committee input also contributed to the vision and guiding principles used in the planning process. Notes from their meetings are found in the appendix.

The current system evaluation and the plan vision and guideposts were reviewed by stakeholder groups on July 29-30, 2019 with representatives from:

- Education
- Business
- Transit/Multi-modal transportation
- Environmental

Stakeholder input is included in this draft plan.

This draft plan is submitted to the City Council for review, possible revision, and adoption. Following adoption, the Department of Public Utilities will hold a series of community meetings to familiarize residents, developers, and stakeholders on the policies, standards and processes included in this plan.

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EXECUTIVE SUMMARY

Salt Lake City requested an evaluation of existing street lighting conditions and a master plan to aid in transitioning all Salt Lake City-owned street lighting from a high pressure sodium system to an LED system, a process begun in 2013. In addition, the master plan identifies methods to improve visibility and aesthetics while reducing energy and maintenance through a lighting control system. The master plan identifies new street lighting standards for retrofit and new construction.

The goal of this document is to provide Salt Lake City with a consistent approach for street and pedestrian lighting that creates a quality nighttime visual experience. Street and pedestrian lighting plays a key role in how people experience the city in which they live, work, and play. Lighting helps drivers and pedestrians understand the streetscape through visual cues and heightened awareness of their environment. Providing good visibility with lighting increases comfort levels and encourages use of public streets and spaces.

The plan identifies a strategy that balances safety, character, responsibility, and equity using a series of guideposts for evaluating the lit environment and the technical elements of a streetlighting system.

CURRENT SYSTEM EVALUATION

The Advisory and Technical Committees along with the consulting team surveyed seventeen locations in the city. In addition, the consulting team conducted nighttime surveys and measured the light levels along primary arterial, minor arterial, collector and local streets. Survey sites were selected in each Council District to represent a variety of existing lighting conditions throughout the city. Based on the survey and evaluations, the consulting team created an Existing Conditions Report (Appendix C) to aid the city in understanding relationship of visual perception to measured light levels.

The consulting team categorized each survey site according to IES standards acceptability light level, lamp wattage, street type, luminaire spacing and measured lighting levels. The four levels of acceptability are:

- **Excellent.** the survey sites identified as "Excellent" received the highest scores from the Advisory and Technical Committees, indicating excellent visibility, appropriate light levels, low glare, uniformity and good color.
- **Acceptable.** the street meets lighting standards based on street classification and existing luminaire spacing. Block faces categorized as "Acceptable" require only LED retrofit.
- **Moderate.** the street does not meet lighting standards based on street classification and existing luminaire spacing. Block faces categorized as "Moderate" require minor improvements to address relatively small dark spaces between poles as well as LED retrofit.
- **Poor.** the street has very low or no street lighting. Block faces categorized as "Poor" require significant investment in new lighting and electrical infrastructure to meet lighting standards.

As seen in Figure 1, of the sites surveyed, 17 percent are categorized as Excellent, 35 percent are Acceptable, 24 percent are Moderate and 24 percent are Poor.

The following policy statements are intended to guide the approach to addressing identified needs and gaps in the City's current street lighting as well as apply to future changes in the system.

Site #	Site Name	Street Classification	Existing Lighting
1	Sterling & American Beauty Dr.	Local / Residential	**Excellent**
2	Riverside Park & 600 North	Arterial / Park	**Acceptable**
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4	700 South & Post Street	Local / Residential	**Poor**
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6	Glendale Dr. & Navajo St.	Collector / Residential / Commercial	**Moderate**
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8	800 East & South Temple	Arterial / Commercial	**Excellent**
9	200 South & Floral St.	Arterial / Commercial	**Excellent**
10	650 South & Main St.	Arterial / Commercial	**Acceptable**
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14	1500 South & Yale	Collector / Residential	**Acceptable**
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16	1400 East & Redando	Local / Residential	**Moderate**
17	1000 East & 2100 South	Arterial / Commercial	**Acceptable**

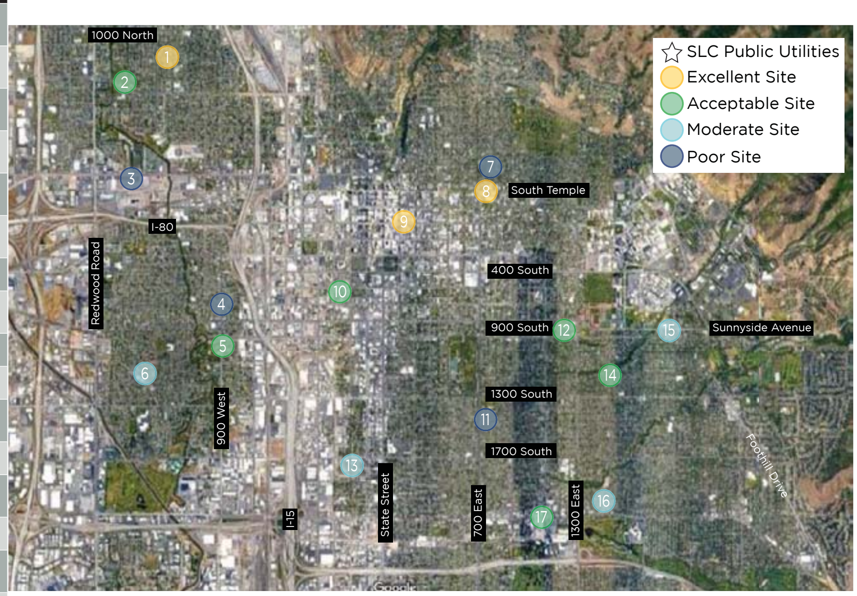

Figure 1: Site Evaluation Map

POLICY STATEMENTS

Based on the application of planning guideposts and input of the steering and technical committees, the master plan implements the following major policies:

- Street lighting will enhance safety through the implementation of industry recognized standards.
- Street lighting standards include allowances to encourage dimming strategies relating to pedestrian activity, wildlife and dark skies lighting.
- Street lighting will minimize the obtrusive effects of light at night resulting from light trespass, light pollution, and glare through the selection and placement of appropriate poles, fixtures, light type, and light levels.
- Provide pedestrian lighting in accordance with neighborhood plans and in accordance with the typologies in this plan.
- Provide street and pedestrian lighting that minimizes impacts to sensitive wildlife species.
- Select fixture types to provide dark skies protection.
- Implementation based on neighborhood and community input to determine pole, fixture type, maximum and minimum light level, and the implementation of adaptive dimming applications when appropriate.

The standards and implementation strategies to achieve Salt Lake City's major street lighting policies are included in this plan. Salt Lake City utilizes IES standards with allowances to respond to pedestrian, wildlife, and dark skies priorities.

IMPLEMENTATION STEPS

Funding and prioritization are the key drivers in implementation of the policies, standards, and strategies in this plan. Road classification and adjacent land use are the driving factors in selection of street lighting type, spacing and light levels. There are neighborhoods and high conflict areas of the City that are recommended for priority implementation.

In all cases, the initial step in implementation is coordination with the community and immediate neighborhood to ensure that the solution identified meets resident, business owner and user needs.

Implementation recommendations prioritize the following:

- PRIORITY ONE:
  - Neighborhoods currently underserved for street and/or pedestrian lighting based on adjacent land uses.
  - High conflict areas including:
    - School Zones
    - Bus Stops
    - Transit Stations
    - Neighborhood Byways
- PRIORITY TWO:
  - Areas with non-compliant existing streetlighting (luminaire, light source or pole spacing)
- ONGOING:
  - Replacement of lamps with LED luminaires on regular maintenance schedule as appropriate
  - Replacement of non-compliant street lighting in areas of ecological sensitivity
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SALT LAKE CITY, UT

Street Lighting Master Plan

VOLUME 1 - MASTER PLAN

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

GSBS CONSULTING

JUNE 2020

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INTRODUCTION TO THE PLANNING PROCESS

The 2020 Street Lighting Master Plan was developed with the input and guidance of two committees and reviewed by a Stakeholders group. The Advisory Committee included representatives from:

- Each City Council District
- Department of Public Utilities
- Mayor's Office

The Advisory Committee met six times during the process to provide guidance on policy issues:

- Street Lighting Site Tour & Surveys (November 5, 2018)
- Street Lighting 101 (April 3, 2019)
- Visioning Session (April 25, 2019)
- Council & Mayor's Office Briefing (May 24, 2019)
- Stakeholder Update (July 30, 2019)
- 50% Progress Update (January 8, 2020)

The Advisory Committee created a list of lighting concerns and priorities for each district across the City as well as provided guidance on the City's street lighting vision and guideposts. Notes from their meetings are found in the appendix.

The second committee was the Technical Committee with representatives from the following City departments:

- Police
- Fire
- Sustainability
- Engineering
- Planning
- Urban Forestry

Technical Committee members represented the interests of their departments in the master planning process. They also participated in the street lighting site tour. Technical Committee input also contributed to the vision and guiding principles used in the planning process. Notes from their meetings are found in the appendix.

The current system evaluation and the plan vision and guideposts were reviewed by stakeholder groups on July 29-30, 2019 with representatives from:

- Education
- Business
- Transit/Multi-modal transportation
- Environmental

Stakeholder input is included in this draft plan.

This draft plan is submitted to the City Council for review, possible revision, and adoption. Following adoption, the Department of Public Utilities will hold a series of community meetings to familiarize residents, developers, and stakeholders on the policies, standards and processes included in this plan.

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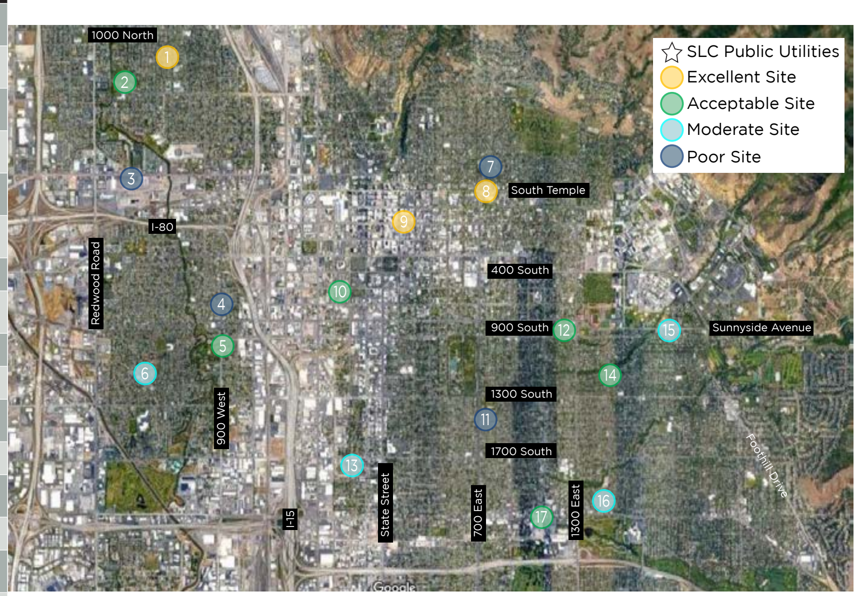

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SYSTEM BACKGROUND, HISTORY

Salt Lake City was the fifth city in the United States to have electric lights. By 1887, streetlights were operating on Main Street and along First and Second South Streets. The City's first systematic plan for locating streetlights was adopted in 1908. The most recent previous update to Salt Lake City's streetlighting plan was completed in 2006 when the system was operated and maintained by the Salt Lake City Transportation Department within the Community Development Department.

In 2012 responsibility for streetlight policy, operations and maintenance was transferred to the Street Lights Department within the Department of Public Utilities. This move coincided with the implementation of a monthly user included in business and residential public utility bills along with drinking water, wastewater, stormwater and sanitation services.

The Department manages and maintains more than 15,500 streetlights in Salt Lake City and has overseen the conversion of the City's inventory to high-energy efficiency LED lamps with a target completion date of 2021. The Department placed the conversion to LED streetlights on hold in 2018 to allow this Street Lighting Master Plan to guide the conversion of the remaining streetlights.

As part of the Street Light Master Plan update, the current system was reviewed and recommendations for changes to the system and updates to Salt Lake City's streetlighting policies were developed. In addition, guidance for installation of new lighting in newly developed areas as well as changes to existing areas is included in Volume 2 - Technical Guidance and Implementation Plan.

The 2012 LED conversion project implements the 2006 Master Plan policy statements. In the interim there have been lighting technology advances, revisions in standards and a new awareness of the impact of exterior lighting on human and environmental health as well as attention to dark skies initiatives. This plan updates Salt Lake City's policies and standards to reflect these advances and changes.

Table 1 provides a comparison of the 2006 Street Lighting Master Plan policy statements and revisions and additions to those policy statements recommended in this update to the Plan.

TABLE 1 - PLAN POLICY STATEMENT COMPARISON 2006 TO 2020

2006 PLAN POLICY STATEMENT	2020 PLAN PRELIMINARY RECOMMENDED POLICY REVISIONS/ADDITIONS
Salt Lake City lighting standards are based on IES recommendations	Revise policy: Salt Lake City lighting standards are based on IES recommendations with allowances for adaptive standards that encourage dimming strategies relating to pedestrian activity, community engagement, wildlife and dark skies lighting.
Lighting level and design will be upgraded to current standards as lights are replaced and new lights are installed	No Change
All newly installed utility lines shall be underground	No Change
When practical installation of underground conduit for utility lines shall be included in road reconstruction projects	No Change
Only dedicated publicly owned streets are eligible for street lighting funded by the City	No Change (Possible future revision for public alleyways. Discussion with transportation and planning.)
Placement of street light poles shall meet safety standards including lateral clearance requirements	No Change
Energy efficient lights shall be used for new and replacement lighting.	Revise policy to balance energy efficiency with human/environmental health. Process to identify areas better suited to amber LEDs primarily for open space and wildlife.
All new streetlights must meet, at a minimum, the "dark sky semi-cutoff" standard with the exception that all new "shoe box" or "cobra head" style streetlights must meet the "dark sky cutoff" standard.	Provide street and pedestrian lighting that reduces the obtrusive effects of light at night, including light trespass that intrudes on private property, light pollution to preserve dark skies, and glare that reduces visibility and annoys drivers, pedestrians and residents.

2006 PLAN POLICY STATEMENT	2020 PLAN PRELIMINARY RECOMMENDED POLICY REVISIONS/ADDITIONS
Lighting appropriate for conditions shall insure uniform and safe lighting on major streets and commercial district streets	No change to the policy. Standards relating to decorative poles and fixtures to be updated.
	Standards relating to private lighting standards in the Northwest Quadrant to be developed.
Public input may be sought regarding fixture and pole type in commercial areas	Additional public input may be sought to determine maximum and minimum light levels on residential collector and local streets for adaptive dimming application.
Residential neighborhoods may adopt a decorative street light fixture and pole from the approved list on non-major streets in accordance with a neighborhood master plan	No Change
All new and replacement lighting shall be from the approved list developed by the City Transportation Engineer	No change to the policy (except departmental designation.) Possible changes to the approved list.
It is the policy of the Salt Lake City Transportation Department to support the use of Crime Prevention Through Environmental Design principles in the design and operation of street lighting within Salt Lake City.	No Change (except departmental designation)
It is the policy of the Salt Lake City Transportation Department to support the use of banners on street light poles to enhance a sense of community and contribute to traffic calming.	No Change (except departmental designation)
It is the policy of the Salt Lake City Transportation Department to coordinate the location of new street lights with the Salt Lake City Forester and, in turn, coordinate on the planting of new trees such that both are compatible in providing desired benefits to the neighborhood.	No Change (except departmental designation)
	Provide street and pedestrian lighting that minimizes impacts to sensitive wildlife species.
	Pedestrian scale lights (typically 12' to 15' mounting height) are on any streets where streetlighting alone does not effectively illuminate the sidewalk due to shadowing from trees, or the location of the sidewalk in relation to the street. Pedestrian scale lights on local residential streets to minimize light trespass and create more pedestrian friendly streets, and in commercial areas to encourage pedestrian usage.

CURRENT SYSTEM EVALUATION

2006 STREET LIGHTING MASTER PLAN

Salt Lake City last published a Street Lighting Master Plan in 2006. While most of the lighting principles and goals from 2006 are continued in this master plan, technical advancements in lighting equipment have allowed improvements to be made in the control and application of light. The 2006 Master Plan pushed the lighting in the city to be safer and more pedestrian friendly while minimizing light pollution and light trespass. It encouraged the use of decorative luminaires to match the character of the neighborhood or enhance downtown commercial districts. These principles of safety and character established in 2006 are guideposts to this Master Plan and will be continued in the lighting strategies and principles throughout the City. The new Master Plan is striving to create a more pedestrian centric city where auto-alternate solutions can be safer and more widely used. The new plan is still encouraging the use of decorative luminaire options in certain areas throughout the city but is requiring enhanced control of light to further minimize light pollution and light trespass.

Since 2006 advances in LED technology have allowed for significant increases in control of light distribution and color. The new Master Plan takes advantage of these advances to recommend the best lighting solutions for each block based on adjacent land use, pedestrian volume, and environmentally sensitive areas. The new plan sets luminaire criteria for lumen output, distribution, and color temperature to ensure appropriate and effective lighting that aims to reduce light pollution and light trespass. Additionally, this master plan provides guidance on lighting controls to help the City establish a citywide wireless control network that will assist in more efficient management and control of streetlights.

SPECIAL IMPROVEMENT DISTRICTS

Certain areas within the City have decorative lighting as a replacement or supplement to the baseline lighting as part of a Special Improvement District. In these residential or commercial areas, the property managers agree to pay the capital costs for new or replacement lighting plus 75% of the ongoing operating and maintenance costs. Special Improvement Districts include the Cactus Poles in the downtown commercial area and the pedestrian post top lights in the Rose Park Neighborhood.

PRIVATE LIGHTING PROGRAM

In 1995 Salt Lake City started the Private Lighting program, allowing residents to purchase, install and maintain streetlights on their blocks. The program is designed to allow the residents of Salt Lake to choose the poles and luminaires that are installed on their block while still ensuring sufficient lighting in the neighborhood. Each block is required to have at least six lights, including at least one at each intersection. Lights are owned by the residents and are connected to home of the owner with underground wiring. Residents can apply for a one-time grant from the city to help offset costs. Depending on funding, the grant can be up to $5,000 per block, but must be matched by the neighborhood, dollar for dollar. The City must approve all lighting equipment and will inspect all installations.

EXISTING LIGHTING CONDITIONS

PROCESS

The Advisory and Technical Committees surveyed seventeen sites in different areas of the city. The sites were selected based on street type, arterial, collector, or residential, and on their surrounding environments in the city, industrial, commercial, transit or residential. The diversity of the sites provide an understanding of the lighting and environmental conditions found in different neighborhoods and along different transportation corridors throughout the city. Only streets, sidewalks and pedestrian paths in the Public Right of Way were evaluated. Privately owned lighting was not included. The survey asked participants about the street and sidewalk lighting conditions at each of the following seventeen sites.

TABLE 2: STREET AND SIDEWALK LIGHTING CONDITIONS COUNCIL DISTRICT LOCATIONS

LOCATION	CLASSIFICATION	COUNCIL DISTRICT
Sterling Drive & American Beauty Drive	Local/Residential	1
700 North & Riverside Park	Arterial/Park	1
Redwood Road & South Temple	Collector/Industrial	1 & 2 Boundary
700 South & Post Street	Local/Residential	2
900 West & Dalton Avenue	Arterial/Residential	2
Glendale Drive & Navajo St.	Collector/Residential/ Commercial	2
J St. & 1st Avenue	Local/Residential	3
800 East South Temple	Arterial/Commercial	3 & 4 Boundary
200 South Floral Street	Arterial/Commercial	4
650 South Main Street	Arterial/Commercial	4
700 East Harrison Avenue	Arterial/Residential	5
900 South & 900 East	Arterial/Commercial	5
Layton Ave. & West Temple	Local/Residential	5
1500 East & Yale Avenue	Collector/Residential	6
1900 East & Sunnyside	Arterial/Residential/Commercial	6
1400 East & Redondo	Local/Residential	7
1000 East & 2100 South	Arterial/Commercial	7

The survey included the following statements to which participants indicated their level of agreement by ranking their response between Strongly Agree and Strongly Disagree.

- It would be safe to walk here alone during daylight hours.
- It would be safe to walk here alone during darkness hours.
- The light is uneven (patchy).
- The light sources are glaring.
- The lighting is poorly matched to the neighborhood.

To supplement survey responses, High Dynamic Range photographs were taken and horizontal and vertical illuminance light measurements recorded for the sidewalks and luminance measurements taken along the roadway at each site. The measurements were compared to recommended levels in the IES Recommended Practice for Roadway Lighting (RP-8-18).

Based on survey results, HDR photographic evidence and light measurements, the consulting team rated lighting at each site as ***Excellent, Acceptable, Moderate*** or ***Poor.***

Excellent rated lighting is sufficient and appropriate on the roadway, provides adequate vertical illumination to allow for object detection and facial recognition. Excellent lighting is relatively uniform, free of direct glare and properly illuminates the roadway and sidewalk.

Acceptable rated lighting is comfortable. In some cases, such as residential areas, the light level might be lower than the IES Recommended Practice but the lack of glare and shadowing from surrounding landscaping, along with some surrounding surface brightness, creates a comfortable nighttime environment without light trespass.

Moderate rated lighting does not provide enough light on the roadway or on the sidewalk. The color of the light may be inconsistent, and the presence of glare may result in an uncomfortable space. Some of these sites were shadowed due to trees, and lighting was not appropriately spaced.

Poor rated lighting occurs when the luminaires are spaced too far apart to provide adequate light levels and uniformity or there are no luminaires on the street at all. These sites included residential areas without sufficient light, industrial sites and an arterial road where lights were malfunctioning.

Of the 17 sites evaluated, three were excellent. Of the excellent sites one is a local residential street and two are arterial commercial streets. Six sites were ranked good. Of the good sites five are arterials, one adjacent to a park, one in a residential area, three in commercial areas, and one is a collector in a residential area. Four sites were moderate. Of the moderate sites two are local residential streets, one is a collector in a residential/commercial area, and one is an arterial in a residential/commercial area. Four sites were rated poor. Of the poor sites one is a collector in an industrial area, two are local residential areas and one is an arterial residential area.

Table 3: Street and Sidewalk Existing Lighting Ratings

SITE #		CLASSIFICATION	EXISTING LIGHTING RATING
1	Sterling Drive & American Beauty Drive	Local/Residential	Excellent
2	700 North & Riverside Park	Arterial/Park	Acceptable
3	Redwood Road & South Temple	Collector/Industrial	Poor
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The ratings provide an understanding of the variety of nighttime environments in different areas of the city and guided the development of improvement options. Each option focuses on improving light levels and uniformity, reducing glare, and enhancing wayfinding.

The full report including site specific metrics can be found in Appendix C.

CITY PLANNING GUIDANCE

PLAN SALT LAKE

In Plan Salt Lake adopted in 2015 the community identified 13 guiding principles. Although not always specifically mentioned, high quality street lighting can contribute to achievement of most of the guiding principles.

Six of the principles can be directly affected through the implementation of quality street lighting:

1/Neighborhoods that provide a safe environment, opportunity for social interaction, and services needed for the wellbeing of the community therein.

4/A transportation and mobility network that is safe, accessible, reliable, affordable, and sustainable, providing real choices and connecting people with places.

6/Minimize our impact on the natural environment.

7/Protecting the natural environment while providing access and opportunities to recreate and enjoy nature.

8/A beautiful city that is people focused.

13/A local government that is collaborative, responsive, and transparent.

Plan Salt Lake includes specific initiatives to that mention street lighting to achieve the Guiding Principles. These include "Incorporate pedestrian oriented elements, including street trees, pedestrian scale lighting, signage, and embedded art, into our rights-of-way and transportation networks" as an initiative to create a safe mobility network. This is a critical initiative to achieve several other initiatives, including overall connectivity and safety in the public realm. Plan Salt Lake also includes an initiative to "promote and expand the city's street lighting program throughout the City" as part of the beautiful city Guiding Principle. This is also a critical initiative to achieve several other initiatives, including reinforcing and preserving neighborhood and district character and providing a strong sense of place.

In addition, implementation of this Street Lighting Master Plan to identify and address current gaps in service and upgrade overall lighting will contribute to the fulfillment of several other of the Guiding Principles.

NEIGHBORHOOD MASTER PLANS

Salt Lake City has completed eleven neighborhood master plans for the areas of the City represented on the map in Figure 2.

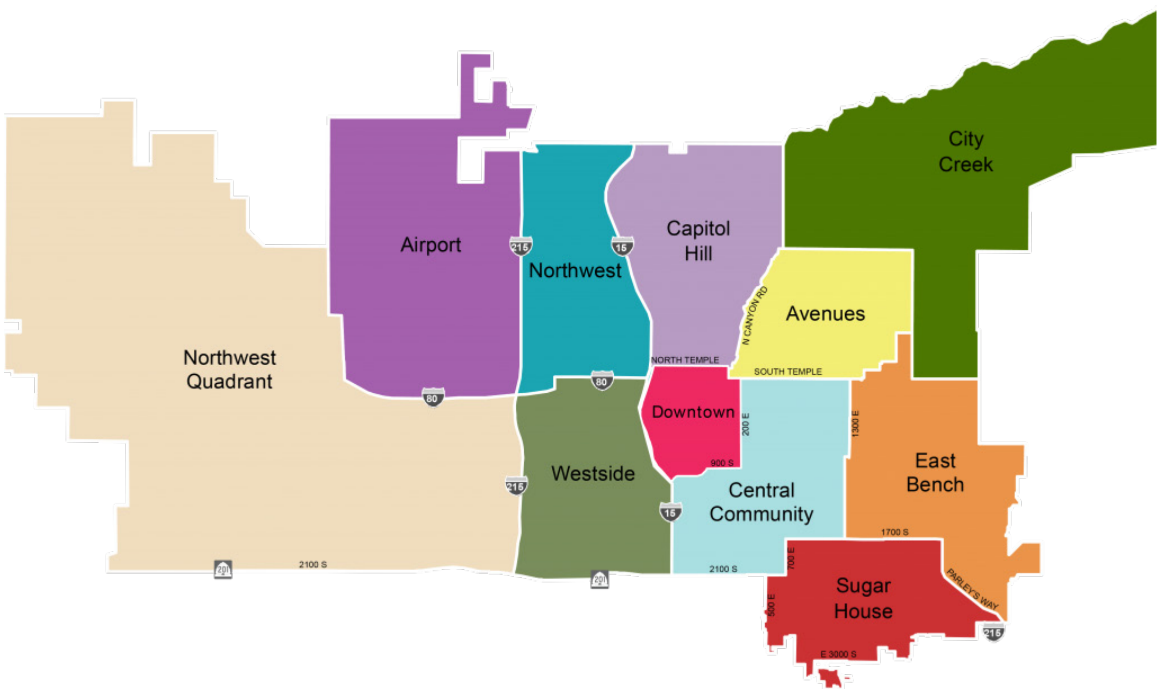

Figure 2: Neighborhood Master Plans Map - 2017

The master plans date from the 1980s through 2017 with amendments and updates. Street lighting is mentioned in many of them as a tool to enhance community character and identify the City's special lighting district program as a tool for implementation. Several of the plans also identify the installation of pedestrian level lighting as a community enhancement strategy.

Some plans identified specific policies and implementation measures relating to street lighting as identified in the table below:

TABLE 4: STREET LIGHTING POLICY AND IMPLEMENTATION ITEMS

COMMUNITY	ADOPTION	GOAL OR POLICY STATEMENT	ACTION OR IMPLEMENTATION ITEMS
Avenues	1987	None	• Streetscape "demonstration project" to illustrate use of streetscape, including street lighting, to improve the neighborhood.
Capitol Hill	1999 Amended 2001	• Coordinate any new street lighting program in designated historic districts with the Historic Landmark Commission to ensure the design of the street lights are compatible with the historic character and comply with the historic district regulations. • Provide a consistent design theme and increase the amount of street lighting on 300 West and 400 West.	• Analyze the feasibility and demand for increasing the amount of street lighting in areas of the Capitol Hill Community where needed and determine funding sources. • Develop and implement a consistent lighting and street furniture theme for the Capitol Hill neighborhood (north of North Temple).
Central	2002 Amended 2006	• Relate right-of-way designs to land use patterns. • Ensure that public streets are maintained and improved throughout the Central Community	• Encourage where appropriate rights-of-way that have landscaped street medians, landscaped park strips, street trees, on-street parking, pedestrian lighting, and furnishings such as major arterials. • Provide consistent neighborhood design themes for street lighting and ensure that street lighting is provided at a pedestrian scale. Coordinate street lighting in designated historic districts with the Historic Landmark Commission to ensure that compatible design and placement patterns are met.

Downtown	2016	• Make downtown a unique destination for visitors. • A complete pedestrian network that makes walking downtown safe, convenient and comfortable. • A public realm that is looked after 24/7. • A downtown known for its well-maintained public realm.	• Maintain and refresh existing policies regarding sidewalk paving materials and street lighting in districts where these items have already been established in this plan or other plans such as the Street Lighting Master Plan. • Address pedestrian safety and comfort issues with regularly planted trees, shortened crossing distances, tighter curb radii, hawk or other pedestrian-activated signals, pedestrian lighting, and regularly spaced benches and seating. • Continue implementation of pedestrian lighting throughout downtown. • Maintain the city improvements such as street lights, seating, and paving.
Westside	2014	• Create a more conducive environment for redevelopment at neighborhood nodes.	• Street lighting should be emphasized at intersections and be scaled to the pedestrian level.

East Bench	2017	• Business Districts that Promote Neighborhood Identity • Improve the Street Rights-of-way to Create Beautiful and Safe Gateway Corridors • Dark Sky Friendly Lighting	• Building features, such as height, placement and materials, as well as street improvements such as signage, landscaping, lighting, paving materials, and pedestrian crossings activate the individual business districts, create a distinct identity, create a sense of place, and help create a more pleasant auto-pedestrian interface. • Establishing a gateway should not stop at creating an entrance feature at the beginning of the street, but should carry through the entire length of the corridor with consistent design treatment, such as street lighting, street furniture, and pavement treatments that relate to the character of each gateway. • The East Bench is the interface between the natural and urban environment. As such the built environment within the community should respect the natural surroundings. One particular aspect of development that can impact both the natural and human environment is lighting. In an effort to minimize disruption to wildlife, impacts on adjacent property, and the community's enjoyment of the night sky, lighting should: - Only be on when needed; - Only light the area that needs it; - Be no brighter than necessary; - Minimize blue light emissions; and - Be fully shielded and pointing downward.
Northwest	1990	None	None
Northwest Quadrant	2016	• Promote the design of transportation corridors that support the natural landscape • North of I-80, provide a common Northwest Quadrant design theme for the public infrastructure, such as native landscaping, lighting, bridge design, signs, etc.	• Use appropriate but minimal levels of lighting to keep sites darker near Natural Areas - Direct lights down and away from natural habitats. - Avoid tall street lights that may negatively impact wildlife habitat. - Use the minimum number of street lights necessary for safety. - Along trails, use lights that only light the trail and not wildlife habitat. • Street lighting should use poles and fixtures that are compatible with the natural environment.

It's clear from Salt Lake City's adopted policy statements and implementation priorities in both citywide and community-level plans that pedestrian level street lighting is an important element for creating a sense of safety and community.

LIGHTING LEVELS & GAPS

Implementation of Salt Lake City's current lighting policy, standards, and approach is illustrated in the streetlight density map in Figure 3.

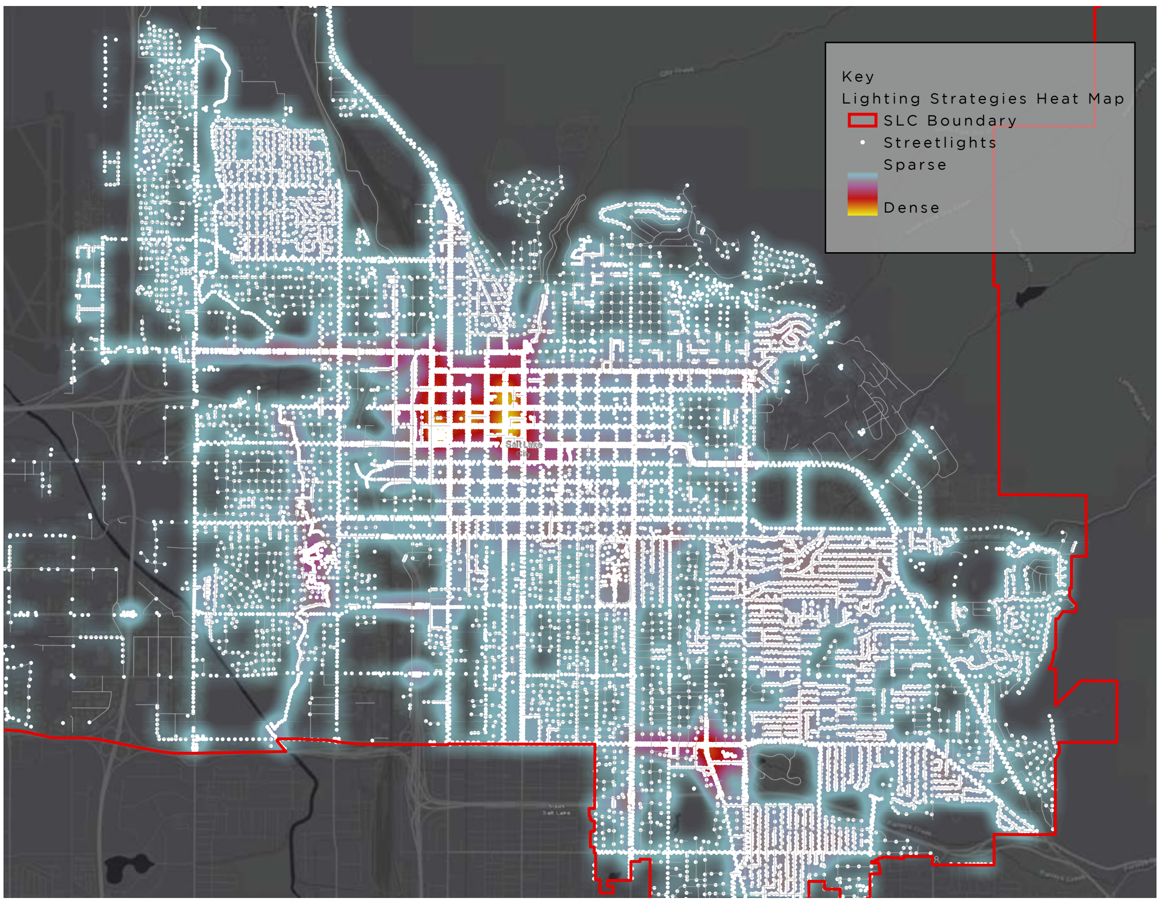

Figure 3: Street Light Density Map

Each streetlight in the City is represented as a white dot on the map. The density of lighting generated is represented from gray and blue in the lowest light density areas to yellow in the highest light density areas. Not surprisingly, the highest density lighting occurs in Salt Lake's commercial areas including downtown and the Sugar House business district and along arterials and other major highways. Lowest light density occurs in residential neighborhoods, parks, and industrial areas. Non-Salt Lake City Public Utilities lighting, including the interstate highways, at the University of Utah and at the Salt Lake International Airport, is not represented.

EVALUATION BY COMMUNITY / DISTRICT

The approach to recommended street lighting improvements in this plan is influenced and informed by the street classification, adjacent land use, pedestrian levels, and specific situations found in each area of the City.

Because past policies focused on street lighting for safety on the City's roads, most areas of the city have lighting in compliance with IES and APWA road safety standards. As seen in the summary adopted master plan goals and implementation measures, many neighborhoods in the city would like to see additional pedestrian level lighting. Figure 4 is a map of the existing character districts in the City.

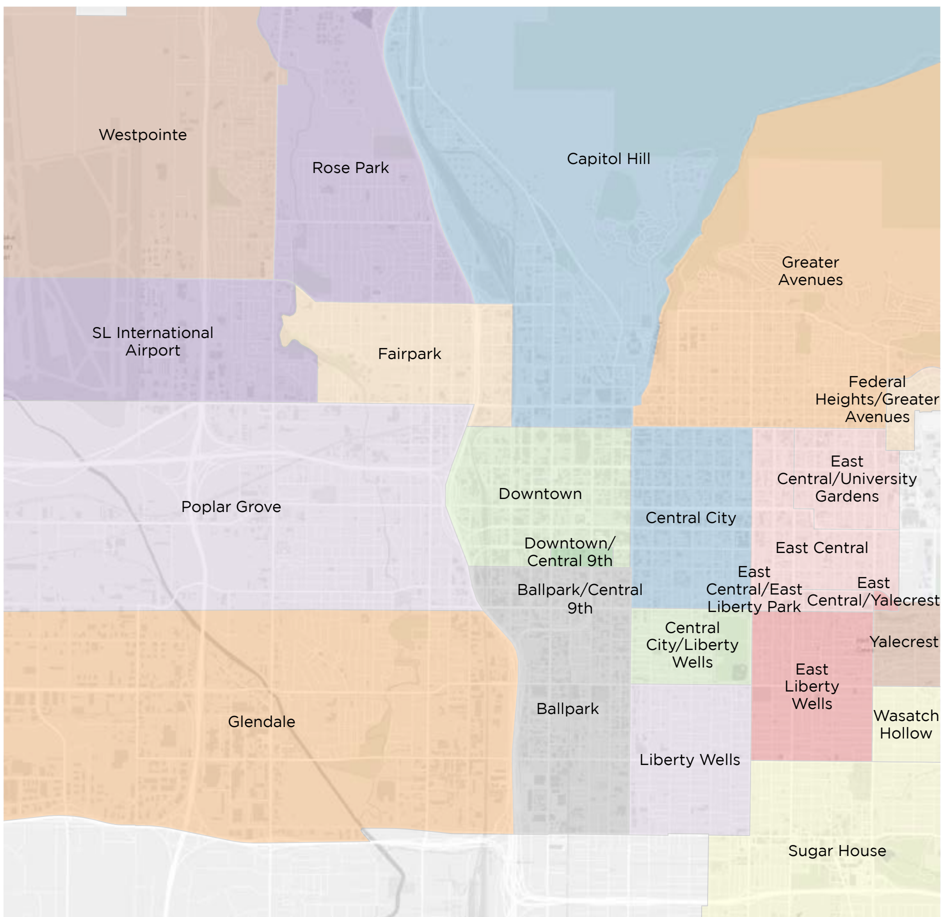

Figure 4: Community Character Map

Residents, developers, and other interested parties can identify existing lighting location and type using the interactive map on the city's website. The map provides the following information:

- Location
- Pole type
- Luminaire type
- Light source

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PLAN GUIDEPOSTS

The Advisory and Technical Committees developed a series of guideposts as a basis of evaluating street and pedestrian lighting characteristics.

The four guideposts:

- Safety
- Character
- Responsibility
- Equity

Lighting improvement strategies and characteristics were evaluated based on these guideposts. The safety, character and responsibility guideposts depend on the district in which the lighting is located and adjacent land uses. The equity guidepost underpins the entire plan and implementation strategy to encourage lighting improvements based on community need. The guideposts are intended to result in design decisions that contribute to safe and comfortable nighttime environments. The application of the guideposts and the design decisions they affect contribute to identifying lighting designs and approaches that best fit the needs of each project.

SAFETY

Appropriate street and pedestrian lighting improves safety by improving visibility for drivers, bikers, and pedestrians. Effective visibility in the nighttime environment depends more on the quality of light than the quantity. Higher light levels do not always result in better visibility. The qualities of light that achieve excellent visibility and therefore improve safety are:

- Appropriate Light Level
- Reduced Glare
- Uniformity vs. Contrast
- Adaptation
- Color

CHARACTER

Salt Lake City's existing street and pedestrian lighting is diverse with a variety of historic and industrial cobra-head style lights. Special Districts use street lighting to create distinct character and enhance the unique identity of the district. The characteristics of street and pedestrian lighting that can support and enhance the character of an area include:

- Scale: Street Scale, Pedestrian Scale
- Style: Luminaires, Mounting Brackets, Poles, Pole Bases, Additional Amenities
- Appropriate Light Level
- Glare
- Color: Finish Color, and Color of Light Source

RESPONSIBILITY

Responsible implementation of street lighting includes minimizing potential negative effects of light intensity and spectrum on human and ecological health balanced with the responsible use of public funds. This is a complex challenge that includes many issues that sometimes require balancing opposing opinions and perspectives. This Master Plan references the latest research in the effects of light intensity and spectrum on visibility and human and ecological health in exterior nighttime environments. To implement the Responsibility guidepost the following issues are considered and balanced:

- Light Trespass
- Light Pollution
- Health & Wellbeing
- Impacts on Wildlife
- Energy Use
- Cost
- Maintenance

EQUITY

The implementation of this Street Lighting Master Plan is intended to address issues related to street lighting in the most equitable way possible. The prioritization of street lighting funding will be an ongoing process within annual budget allocations. Recognizing that there are differing opinions throughout the City about the balance between the Guideposts and how to implement the Lighting Strategies in this master plan, particularly in residential neighborhoods, it is important that there is ongoing public engagement to determine the appropriate lighting strategies within each neighborhood. While some lighting strategies will be optional, there are some minimum requirements for lighting improvements to address safety needs in a consistent way throughout the Salt Lake City.

- Ongoing Public Engagement
- Prioritizing Areas Currently Underserved by Street Lighting

STREET LIGHTING BASICS OVERVIEW

SYSTEMWIDE CONSIDERATIONS

HEALTH AND WELLBEING

The natural daily cycle of light and dark is directly linked to the healthy sleep/wake cycles, also known as circadian rhythm. Light is the primary stimulus that triggers the suppression of melatonin in humans. Darkness at night is needed to allow the production of melatonin for healthy and complete sleep. Exposure to blue spectrum light after sunset can delay the nighttime production of melatonin. Controlling glare and light trespass and using light sources with warmer color reduces the exposure to blue spectrum content of LED for street, pedestrian, and area lighting. Warmer colors encourage healthy melatonin and sleep patterns for residents. It is also important to note that the current status of research related to light exposure at night and human health is still ongoing. According to the Lighting Research Center[1] at typical street lighting levels, per IES RP-8-18, using LED light sources are “below the threshold for suppressing nocturnal melatonin (in humans) by light at night following a 30-minute exposure”.

WILDLIFE IMPACTS

Salt Lake City contains important wildlife habitat, from the foothills in the east to the open shore lands of the Great Salt Lake. Additional wildlife habitat is found along the north-south route of the Jordan River and along the four urban creeks extending west and south out of the foothills. Light at night can disrupt these wildlife habitats. Migratory species pass through the city itself, with nocturnally migratory birds attracted to the city lights. Controlling light pollution and light trespass, using only necessary lighting levels, and choosing an appropriate spectrum (color) of light for each area can protect these natural resources. Dimming lights during seasonal bird migrations is another wildlife-friendly approach.

LIGHTING CHARACTERISTICS

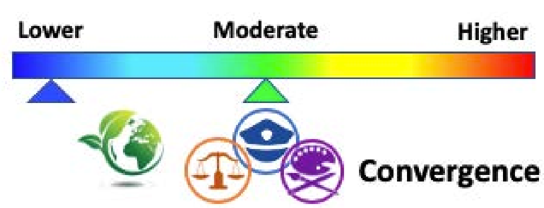
Each of the following characteristics represent considerations and decisions to be made in implementing street lighting in the various areas and neighborhoods of the city. Each characteristic is evaluated based on each of the guideposts. When one or more of the guideposts converge and coalesce around the characteristic, synergy is created. When the guideposts diverge decisions must be made to balance competing needs.

Each characteristic is identified and described then evaluated based on four Guideposts. A comparative example of the characteristic is also included to enhance understanding of the concept.

APPROPRIATE LIGHT LEVELS

Appropriate light levels vary based on roadway classification, adjacent land use, pedestrian activity, and proximity to open space and wildlife habitat. The recommendations in the plan apply adaptive lighting criteria to the Illuminating Engineering Society’s Recommended Practice for Street and Roadway Lighting (IES RP-8-18) to allow for dimming during reduced pedestrian activity and the use of broad spectrum, white light sources, such as LED.

Figure 5: Appropriate Light Level



Character, Safety and Equity converge around moderate light levels.

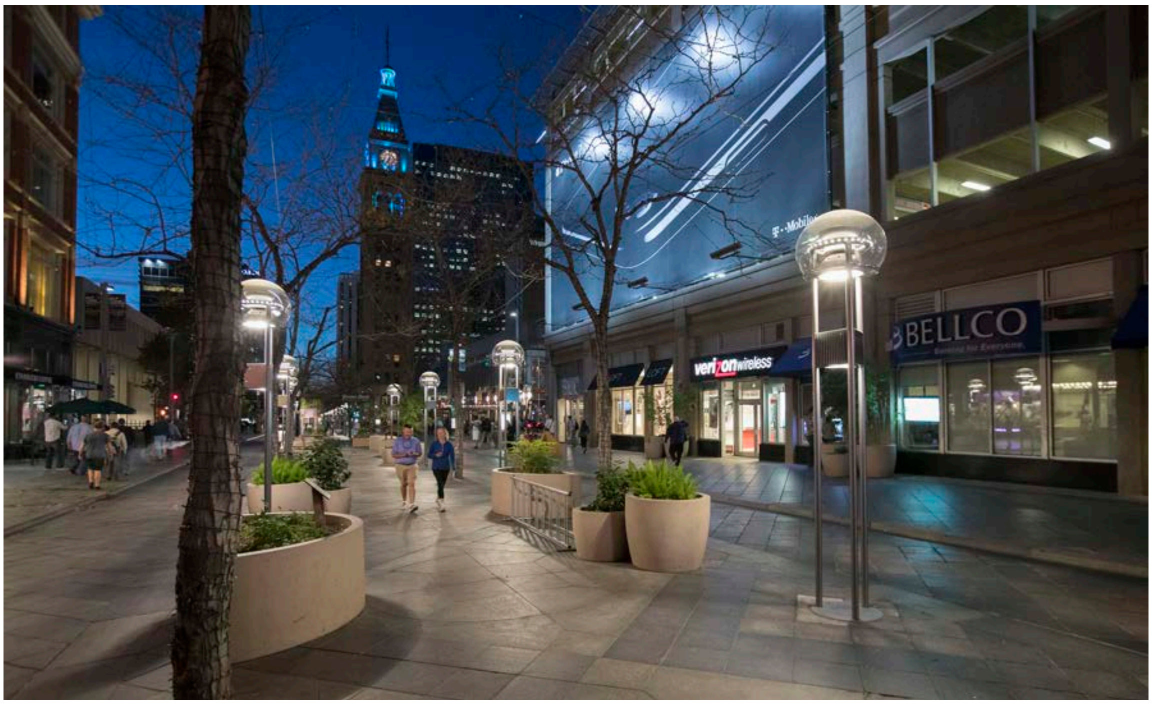
- Using appropriate amounts of light increases nighttime visibility creating a safer and more comfortable environment.

[1] *Rea MS, Smith A, Bierman A, Figueiro MG. 2012. The potential of outdoor lighting for stimulating the human circadian system. Alliance for Solid-State Illumination Systems and Technologies (ASSIST)*

- The City is working to upgrade lighting to appropriate light levels based on locations with the greatest need.

Appropriate light levels are balanced with environmental responsibility.

- In environmentally sensitive areas, lower light levels are desired. The City will be installing more environmentally friendly luminaires with a lower CCT and better glare control

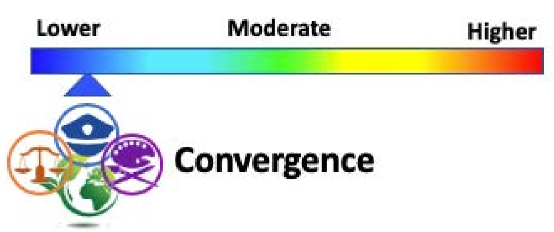


Appropriate Light Levels: This photo demonstrates appropriate light levels for a commercial area with medium to high pedestrian usage, where moderate light levels provide excellent visibility through out the public streets and sidewalks.

GLARE REDUCTION

Glare is caused by excessive or undesirable light entering the eye from a bright light source. Glare can result in discomfort, annoyance, and decreased visibility. There is the potential for direct glare when a light source is in direct view. The presence of direct glare depends on the intensity of the light source and contrast with the surrounding environment. With direct glare, the eye has a harder time seeing contrast and details. A lighting system designed solely on lighting levels aim more light at higher viewing angles, thus producing more potential for glare. Direct glare can be minimized with careful equipment selection as well as placement.

Figure 6: Glare Reduction



Character, Safety, Equity, and Responsibility converge around reducing glare levels as it leads to more effective lighting and safer, more comfortable environments.

Reducing glare:

- Improves visibility on the roadways
- Creates a more enjoyable nighttime environment
- Reduces sky glow and light trespass, minimizing the obtrusive effects of light.

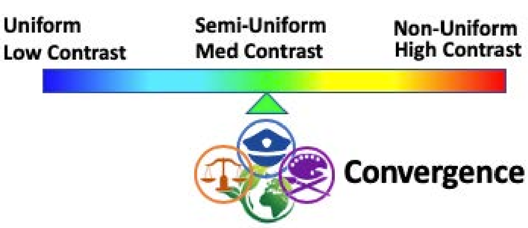
Lights that create glare can result in a range of negative effects for drivers, pedestrians and residents. From annoyance to reduced visibility, and may generate complaints from residents.

Lights with low glare provide more comfortable streets and public spaces, providing lights, where it is needed without annoying nearby residents.

UNIFORMITY VS. CONTRAST

Lighting uniformity refers to the evenness of light. Our eyes are continually adapting to the brightest object in our field of view. Any object lighted to 1/10 the level of the immediate surroundings appears noticeably darker. For roadway lighting, good uniformity indicates evenly lighted pavement. However, good visibility requires the contrast of an object against the background. An environment with perfectly uniform lighting provides low contrast, which can reduce visibility. To create enough contrast for good visibility, there should be a balance between uniform perception and having enough contrast to improve visual detection of objects on the road. Uniformity criteria are typically described as ratios of maximum to minimum and average to minimum luminance or Illuminance. Contrast is the difference between two adjacent luminance values. High contrast is necessary for good visibility. Differences in color also produce a visible contrast, even when both objects have similar luminance values, which support the benefits of using higher color rendering sources, as discussed below in the Color Rendering and Nighttime Visibility section.

Figure 7: Uniformity Vs. Glare



Character, Safety, Equity, and Responsibility converge around semi-uniform medium contrast lighting. This provides the proper balance of uniformity and contrast and is essential to quality lighting design.

- Safety on the roadway is improved when street lighting properly strikes this balance, and subtle contrast can add character to an area with a unique lighting design.
- When the proper balance of uniformity and contrast is achieved, the lighting is more effective at lower light levels reducing over lighting and light pollution.

Color Contrast: In the photos above, the black-and-white image shows that the luminance of the flower and background are very similar. Only when the color is rendered does the color contrast of the yellow flower make it highly visible next to its background. This demonstrates why street lighting with good color rendering can improve visibility of objects in a street, even at the same, or lower light levels. Further study on the effects of color contrast in street lighting applications is needed to understand the improved visibility of broad spectrum light sources at light levels below current IES RP-8-18 recommendations.[2]

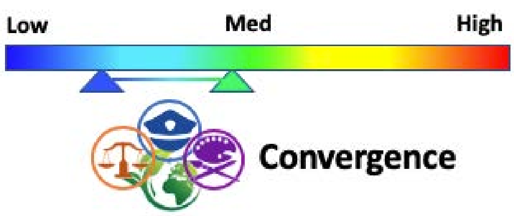
[2] *Clanton N, Gibbons R, Garcia J, Mutmansky M. 2014. Seattle LED Adaptive Lighting Study. Northwest Energy Efficiency Alliance Report #E14-286*

ADAPTATION

Adaptation refers to the eye's ability to adjust between changes in luminance. Our eye will automatically adjust to the brightest object in our field of view. Glare from headlights or fixed lighting can affect one's ability to adapt to lower surface luminance. This is especially true as one ages. Another form of adaptation occurs when driving from a brightly lighted area to a non-lighted section of roadway. Here, the lighted area should slowly transition to darker to allow adaptation time. Off roadway brightness, such as driving past a brightly lighted gas station or LED sign, can also cause adaptation issues. While this Master Plan does not directly address lighting on private property, it is intended to set an example for future lighting guidelines that could apply these lighting strategies to all exterior lighting in Salt Lake City.

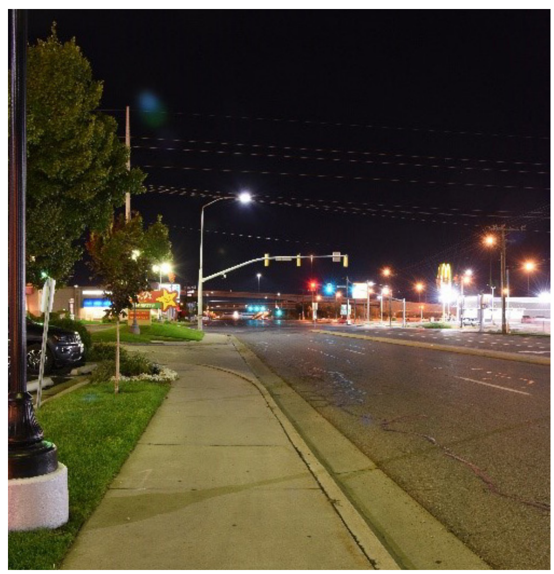
The privately owned lighting at this auto dealership are too bright and lack proper shielding creating high adaptation issues transitioning from the sales lot to the street.

Figure 8: Adaptation



Character, Safety, Equity, and Responsibility converge around low to medium levels of visual adaptation to improve visibility when transitioning from private parking lots and property into public streets.

- When street lighting and adjacent private lighting is designed to appropriate light levels, the eye can maintain a proper degree of adaptation. When the eye is adapted to the existing light, it is more effective at detecting and identifying objects, increasing safety.



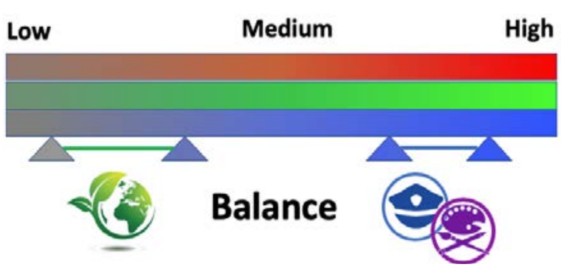
When roadways are illuminated to appropriate light levels with good control of light, the eye is able to adapt, increasing visibility and safety on the streets.

COLOR RENDERING AND NIGHTTIME VISIBILITY

The Color Rendering Index (CRI) is the standard metric used to evaluate how well a light source renders the true color of an object. CRI is measured on a scale of 0 to 100, with 100 representing how an object would look under a reference incandescent light source. The higher the number, the better the color rendering capacity. Traditional High-Pressure Sodium ("HPS") streetlights have a very low CRI of approximately 30, making color detection difficult. Today's standard LED streetlights are not only significantly more energy efficient, they also have a much higher CRI, typically 65 or higher, increasing color detection, visual acuity, and overall effectiveness of the streetlights. LED lighting technology advancements allow streetlights to be tuned to a specific correlated color temperature ("CCT") without drastically reducing the CRI. This technology can be used to reduce the color temperature in environmentally sensitive areas without significantly reducing the CRI, preserving the effectiveness of the lighting system.

LED's emit light across the visual spectrum, considered white light, which appears brighter at night. When traditional HPS lights are replaced with LED's similar light levels often appear to be much brighter with LED lights. Residents may find the light to be obtrusive. When upgrading to LEDs in residential areas, it is essential to have a dimming system to respond to complaints from residents.

Figure 9: Color Rendering



Safety and character converge around using higher CRI of 65 or higher. Eliminating blue spectrum light with lower CRI is responsible in areas with critical wildlife habitat.

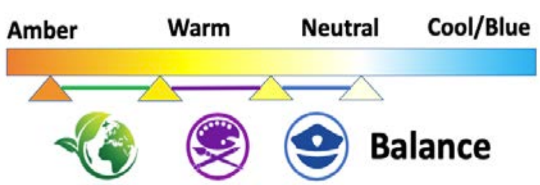
- Using a higher CRI improves safety by increasing visual acuity and object detection, making the roads safer or vehicles and pedestrians.
- Higher CRI improves character in the area by enhancing colors of landscaping and objects within the streetscape.
- Within or adjacent to critical wildlife areas a luminaire with a lower CRI and CCT should be used to responsibly illuminate the area while also minimizing impacts on wildlife.

This car is illuminated by two different light sources. On the left, an LED light, with high color rendering, clearly reveals the color and details of the car. On the right, a low pressure sodium light, with low color rendering, distorts the color of the car and details of the vehicle are not clear.

COLOR TEMPERATURE AND NIGHTTIME VISIBILITY

Appropriate Correlated Color Temperature (CCT) of streetlights is largely depends on the location of the lights within the city. Salt Lake City consists of diverse land uses, ranging from high density urban areas to environmentally sensitive lowlands and foothills. Street type and adjacent land use determine the appropriate color of light.

Figure 10: Color Temperature



There are opposing effects on how the spectrum of light at night affects visibility for Safety and human and environmental health for Responsibility. Limiting the CCT of light sources for the City to a maximum of 3000K, and then adjusting to warmer CCT in residential and wildlife habitats provides a balance between the guideposts. CCT should vary throughout the City to achieve comfortable, safe and responsible street and pedestrian lighting throughout the City.

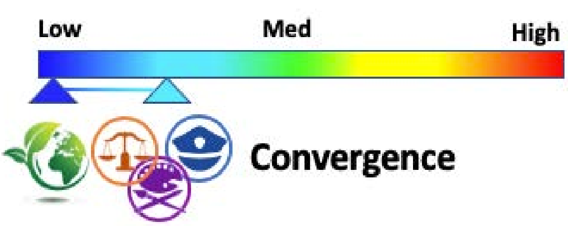
- High Density Urban Areas – 3000K CCT (max). Lighting in higher density urban areas should prioritize color rendering for color contrast and object detection on the roadway. This increases visibility for drivers and pedestrians. In urban areas light should have a CCT of 3000K. This CCT is considered a warm white light source, which improves visibility at night, but also minimizes the amount of light in the spectrum that can cause disruptions to the surrounding environment as well as human health. The American Medical Association and International Dark Sky Association both recommend a maximum CCT of 3000K.
- Residential Areas – 2700K CCT (max). Visual acuity from white light sources is needed for pedestrian safety, but residents typically prefer a warmer color temperature in their neighborhood. The recommended color temperature for residential local and collector streets is 2700K. On arterial streets in residential areas, 3000K CCT should be used due to increased speeds. This range will provide the appropriate amount of white light to preserve object detection but will also allow a warmer, more comfortable color of light in neighborhoods.
- Environmentally Sensitive Areas – 2200K CCT (max). There are varying types of environmentally sensitive areas within and along the perimeter of the city. Where streets pass through or adjacent to environmentally sensitive areas, very warm, phosphor-converted amber light sources with CCT of 2200K or lower, should minimize impacts of light on plants and animals in the area. Additional shielding of both back light and front light may also be required to further reduce light trespass into these sensitive areas.

In the distance, the warm amber glow of low CCT (1800K) high pressure sodium street lights is shown in comparison to higher CCT (4000K) LED street lights in the foreground.

LIGHT TRESPASS

Light trespass is defined as a stray light that crosses a property boundary. The most obtrusive form of light trespass is often caused by an excessively bright luminaire that is unshielded and distributes light into adjacent property. Uncontrolled, non-shielded light sources are usually the cause of light trespass. However, even a controlled, fully shielded luminaire may cause light trespass if not properly located or oriented. In cases where the location of a light standard cannot be changed, additional shielding may be necessary to prevent light trespass. Although designers should always strive to minimize light trespass, sometimes higher levels may be acceptable in downtown, commercial, and area adjacent to civic land uses.

Figure 11: Light Trespass



The following strategies will identify acceptable levels of light trespass to balance the design guideposts.

- When designing in residential areas and environmentally sensitive areas, minimizing light trespass should be the highest priority.
- When designing in downtown commercial or retail environments, pedestrian safety should prioritize increasing vertical light levels in crosswalks.
- The character of a certain light may result in high levels of light trespass, but designers should strive to find luminaires that meet the character of the area while still maintaining zero uplight and minimizing light at angles known to be obtrusive.

A pedestrian light with inappropriate light distribution and poor shielding creates a significant amount of light trespass on a nearby residence.

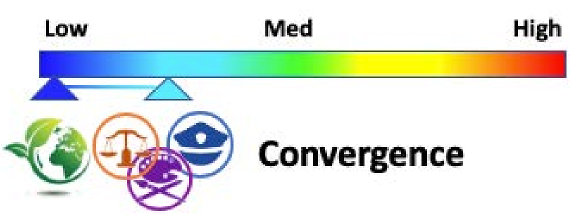
A well shielded street light with appropriate light distribution provides adequate light for the street and sidewalk with minimal light spill beyond the sidewalk.

LIGHT POLLUTION

Light pollution and sky glow are caused by light aimed directly up into the sky and by light reflected from the ground or objects. Any additional light will add to light pollution. However, it is the direct uplight component that does not contribute to useful street level visibility, and is the most objectionable form of pollution. Unshielded luminaires are major contributors to sky glow. Over lighting, even with fully shielded or U0 luminaires, reflects unnecessary light into the atmosphere and adds to sky glow. To minimize light pollution, first minimize the overall amount of light. Exterior lighting should be used only where and when it is needed. Define the lighting requirements of each street or public area and provide only the necessary lighting. Street and pedestrian lighting in residential areas should be dimmable and have house side shielding options to allow the City to proactively address specific complaints about light pollution or light trespass.

All lighting in the city should be designed based on the criteria in this plan to reduce over lighting. In addition, lighting should be shielded and dimmable.

Figure 12: Light Pollution



The strategies to limit light pollution are similar to those identified for Light Trespass.

- Lighting in environmentally sensitive areas should always prioritize minimizing light pollution by not over lighting and using luminaires with zero uplight and minimal light at high angles.
- In areas of heavy pedestrian traffic, light at higher angles may be necessary to provide the vertical illuminance and positive contrast to safely light crosswalks with more light at higher angles.
- Decorative luminaires can contribute more to sky glow, but designers can still install decorative luminaires with minimal uplight component that maintain the historic character of the area.

The historic acorn style lights currently used on the Downtown "Cactus" pole distribute a significant amount of light upward, contributing to increased light pollution and sky glow.

COSTS AND IMPLEMENTATION

The implementation of this Street Lighting Master Plan will require additional investment in the lighting and electrical infrastructure throughout Salt Lake City and multiple years to install. To ensure the equitable distribution of street lighting improvement projects, this Master Plan recommends how the City prioritizes these projects and some changes in the funding mechanisms. The current funding strategy provides a base level of street lighting under the standard Public Utility Street Lighting Fee. To apply for additional pedestrian scale lighting under the Special Improvement Districts program, an additional fee is required to install pedestrian scale lighting in a specific neighborhood. This results in more affluent neighborhoods with more lighting than less affluent neighborhoods. The City should develop an alternative funding mechanism that provides more equitable distribution and access to pedestrian scale lights throughout the City, not just in areas that can afford the additional fees.

INITIAL COSTS

The initial investment in street and pedestrian lighting improvements will vary based on the strategy chosen to bring the current system into compliance with this plan. Comprehensive improvements, such as lighting redesign, will have the highest initial costs, whereas 1-for-1 replacements of existing luminaires will have lower initial costs. In many areas the 1-for-1 replacement strategy will achieve plan purposes. Other areas require more comprehensive improvements, such as relocation of poles or installation of new lighting. Costs included design and engineering costs (Design & Construction Documents, Utility Surveying), lighting equipment costs (Luminaires, Poles, Lighting Controls), and infrastructure costs (Foundations, Conduit & Wire, Surface Replacement).

Figure 13: Initial Costs: Guidepost Synergy & Balance

The public engagement process identified that increasing the use of pedestrian scale lighting is a community-wide high priority. Prioritization of pedestrian scale lighting upgrades include:

- Lighting upgrades and additional pedestrian lighting in currently underlit areas.
- Strategic placement and appropriate light levels will minimize power consumption and eliminate unnecessary equipment.
- Lighting upgrades and new projects in areas identified as critical wildlife habitats using proper equipment and lighting levels.

LONG TERM LIFE CYCLE COSTS

- Changing to LED lighting will drastically reduce the life cycle and operating costs of the street lighting system. LED lighting requires significantly less power than legacy sources, such as high-pressure sodium, reducing the life cycle energy costs of the system. With a lifespan of up to 100,000 hours, LEDs need to be replaced significantly less often than legacy luminaires, reducing maintenance costs.
- Energy Costs (Luminaire Watts, Dimming, Part-Night Lighting, Annual kWh baseline, Annual kWh projected)
- Maintenance Costs (Minimizing Lighting Equipment SKUs, Equipment Life)

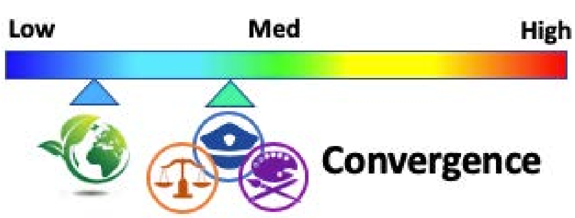
MAINTENANCE

- Proper maintenance is critical for the effectiveness of the lighting design. LEDs are known for their durability, longevity, and consistency in lighting, but quality components are essential to ensure this. The LED electronic driver will fail first if a low-quality luminaire is purchased. Planning and budgeting for high-quality luminaires ensures a longer lifespan with much less required maintenance.
- Another aspect of maintenance involves the dirt and dust that can accumulate inside or on the outside lenses of luminaires. Because street lighting will rarely, if ever, be cleaned, luminaires must have adequate ingress protection (IP) against dust and water. Requiring the use of street and pedestrian luminaires with a minimum rating of IP65 means that the luminaire is dust-tight and watertight.

ENERGY

Reducing energy use in Salt Lake City can be achieved by using energy efficient LED light sources, providing appropriate light levels without over-lighting, and reducing light levels after a curfew by dimming or turning off non-essential lighting.

Figure 14: Energy



Reduction in Energy use for street and pedestrian lighting is consistent with the guideposts as transitioning all lighting to LED significantly reducing the amount of energy that will be used.

- The City is striving to reduce over lighting by installing a control system to allow for dimming and further reduction of lighting, adding to the energy savings.
- In more environmentally sensitive areas, this master plan requires phosphor converted amber LEDs with additional shielding. Although these do not use as much energy as legacy light sources, they are still not as efficient as broad spectrum white LEDs. These lights will be used to reduce the adverse effects of lighting on the wildlife in ecologically sensitive areas.

STANDARDIZATION

Salt Lake City has a very diverse street and pedestrian lighting system that utilizes historic decorative lights of various types and provides distinct character to different districts within the City. Providing variety of character requires Public Utilities to stock more components to service and maintain the lighting system. While this Street Lighting Master Plan establishes Character as one of its Guideposts, this must also consider the balance with Responsibility to minimize costs and inventory for Public Utilities to manage and maintain the street and pedestrian lighting system within their budget.

To strike this balance between Character and Responsibility, this Street Lighting Master Plan intends to provide some variety of options within a set of Standardized Components.

- Luminaire Styles
- Pole Styles
- Armature Styles
- Base Styles
- Color Options

STREET LIGHTING PLAN

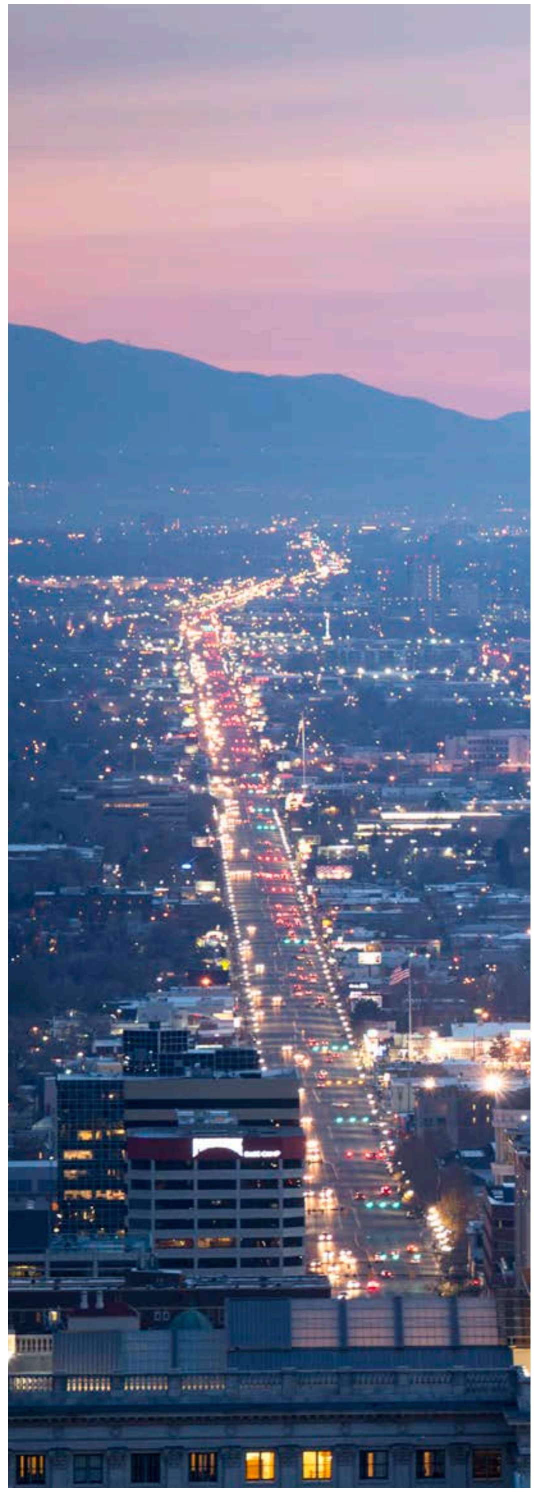
LIGHTING IMPROVEMENT STRATEGIES

PURPOSE

There are several strategies the city can use to implement this Street Lighting Master Plan and improve the quality of street and pedestrian lighting. Each of the strategies will result in a safe environment for drivers and pedestrians while using equipment that minimizes light pollution and light trespass. The plan recommends that the city utilize each of the strategies as appropriate for the specific current streetlighting configuration, road classification, pedestrian volume adjacent land use, neighborhood or districts character and the presence of environmentally sensitive wildlife areas. In addition, each strategy should be discussed through a neighborhood engagement process and reviewed to ensure an optimal balance of the four guideposts is achieved.

LIGHTING LAYOUT STRATEGIES

Volume II – Technical Lighting Development Guide of this Master Plan provides a matrix by which the appropriate strategy should be identified using street types and warrants. The matrix is applied on a block by block basis to ensure the most appropriate lighting for each area. Figure 15 is a snapshot of the Salt Lake City Lighting Warrants matrix described in more detail in Volume II.



SLC Lighting Warrants

Arterial Street

	PED	Existing Conditions	Street Lighting		Ped Lighting
Commercial	High	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous
	Med	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.
	Low	Sidewalk Lit By Streetlight	Non-Cont.		NA
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA
Office Park	Low	Sidewalk Lit By Streetlight	Non-Cont.		NA
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA
Downtown	High	Cactus Poles	Continuous Cactus Pole Lighting		
		Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous
	Med	Cactus Poles	Continuous Cactus Pole Lighting		
		Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.
Industrial	Low	Sidewalk Lit By Streetlight	Int. Only		NA
		Sidewalk NOT Lit by Streetlight	Int. Only		NA
Multifamily Residential	Med	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.
Single Family Residential	Low	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	Optional	Non-cont.
Open Space	Med	Sidewalk Lit By Streetlight	Non-Cont.		NA
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA
	Low	Sidewalk Lit By Streetlight	Int. Only		NA
		Sidewalk NOT Lit by Streetlight	Int. Only		NA

Collector

	PED	Existing Conditions	Street Lighting		Ped Lighting
Commercial	High	Sidewalk Lit By Streetlight	Continuous	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous
	Med	Sidewalk Lit By Streetlight	Continuous	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.
	Low	Sidewalk Lit By Streetlight	Non-Cont.		NA
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA
Office Park	Low	Sidewalk Lit By Streetlight	Non-Cont.		NA
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA
Downtown	High	Cactus Poles	Continuous Cactus Pole Lighting		
		Sidewalk Lit By Streetlight	Continuous	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous
	Med	Cactus Poles	Continuous Cactus Pole Lighting		
		Sidewalk Lit By Streetlight	Continuous	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.
Industrial	Low	Sidewalk Lit By Streetlight	Int. Only		NA
		Sidewalk NOT Lit by Streetlight	Int. Only		NA
Multifamily Residential	Med	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.
Single Family Residential	Low	Sidewalk Lit By Streetlight	Non-Cont.	OR	Non-cont.
		Sidewalk NOT Lit by Streetlight	Int. Only	&	Non-cont.
Open Space	Med	NA			
	Low	Sidewalk Lit By Streetlight	Int. Only		NA
		Sidewalk NOT Lit by Streetlight	Int. Only		NA

Local

	PED	Existing Conditions	Street Lighting		Ped Lighting
Commercial	High	Sidewalk Lit By Streetlight	Continuous	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Non-cont.	&	Continuous
	Med	Sidewalk Lit By Streetlight	Non-Cont.	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Non-cont.	OR	Continuous
	Low	Sidewalk Lit By Streetlight	Int. Only	OR	Non-cont.
		Sidewalk NOT Lit by Streetlight	Int. Only	OR	Non-cont.
Office Park	Low	Sidewalk Lit By Streetlight	Int. Only	OR	Non-cont.
		Sidewalk NOT Lit by Streetlight	Int. Only	OR	Non-cont.
Downtown	High	Cactus Poles	Continuous Cactus Pole Lighting		
		Sidewalk Lit By Streetlight	Continuous	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Non-cont.	&	Continuous
	Med	Cactus Poles	Continuous Cactus Pole Lighting		
		Sidewalk Lit By Streetlight	Non-Cont.	OR	Continuous
		Sidewalk NOT Lit by Streetlight	Non-cont.	OR	Continuous
Industrial	Low	Sidewalk Lit By Streetlight	Int. Only		NA
		Sidewalk NOT Lit by Streetlight	Int. Only		NA
Multifamily Residential	Med	Sidewalk Lit By Streetlight	Int. Only	&	Continuous
		Sidewalk NOT Lit by Streetlight	Int. Only	&	Continuous
Single Family Residential	Low	Sidewalk Lit By Streetlight	Int. Only	Optional	Non-Cont.
		Sidewalk NOT Lit by Streetlight	Int. Only	Optional	Non-cont.
Open Space	Med	NA			
	Low	Sidewalk Lit By Streetlight	Int. Only		NA
		Sidewalk NOT Lit by Streetlight	Int. Only		NA

Figure 15 - Street Lighting Warrants Matrix

This section summarizes the strategies identified in the matrix.

STREET LIGHTING ONLY

PURPOSE

- Quality street lighting must consider the entire context of the streetscape environment, extending beyond the street itself to provide quality light for sidewalks while controlling obtrusive light trespass, glare and light pollution.

- Street trees with large canopies and thick foliage are integral to the character of Salt Lake City's streets and public realm. Street Lighting Only can be a successful strategy in areas that have smaller and fewer trees but may result shadowing sidewalks on streets with large trees.

- The wide streets and right-of-way in Salt Lake City provide opportunities on many streets to have a very wide Park Strip that separates the sidewalk from the street. The width of the Park Strip also affects the ability of Street Lighting Only to effectively illuminate the sidewalks.

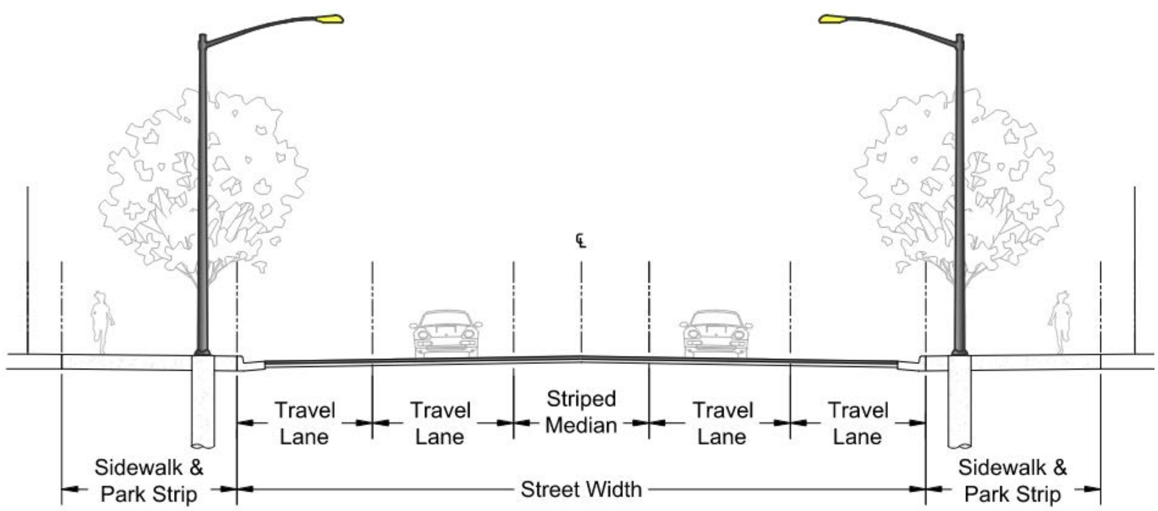


Figure 16: Street Lighting Only Cross Section

STREET AND PEDESTRIAN LIGHTING

- A combination of Street and Pedestrian Lighting is used in areas of high pedestrian activity, and on streets with street trees that create shadowing, or with wide Park Strips where Street Light Only is ineffective at illuminating the sidewalks. This will support a safer and more visually comfortable pedestrian environment.

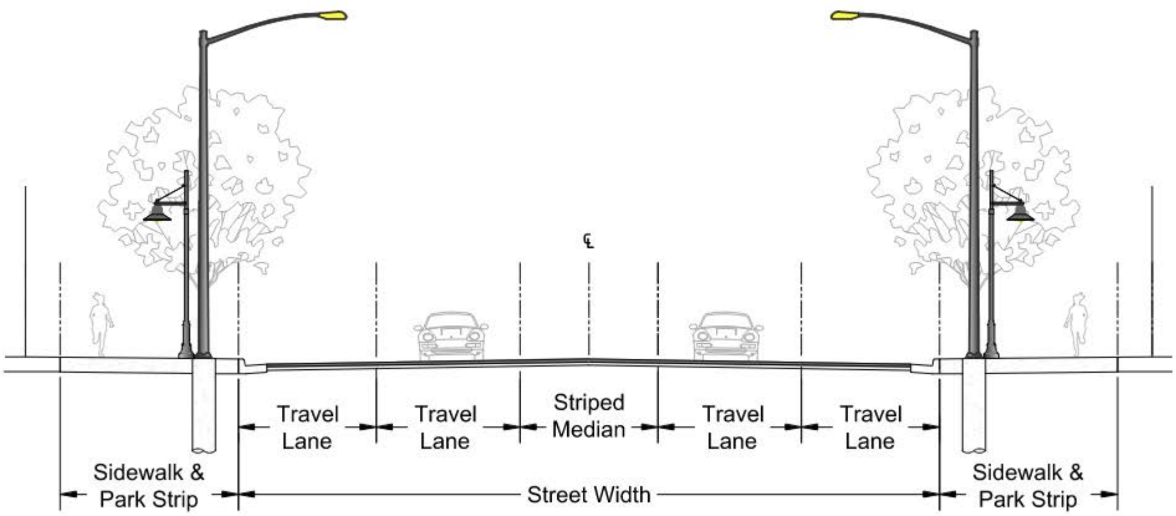


Figure 17: Street & Pedestrian Lighting Cross Section

PEDESTRIAN LIGHTING ONLY

- Pedestrian lighting helps differentiate an area as pedestrian centric and is a visual cue for drivers to be more aware of people in the public right of way.
- Pedestrian lighting in residential areas reduces light trespass into homes, and the character of the lights can differentiate neighborhoods throughout the city.
- In downtown environments, pedestrian lighting identifies restaurants, retail and other pedestrian centric areas, creating a more inviting and safer place for people walking the city.
- When using this Pedestrian Lighting Only strategy, street lights should still be located at intersections.

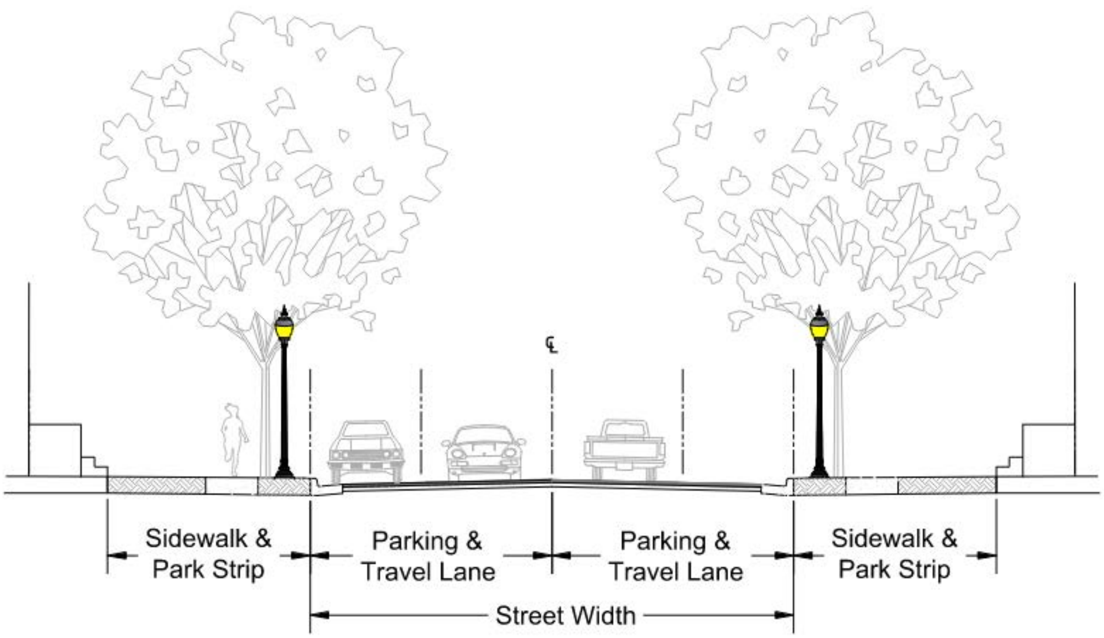


Figure 18: Pedestrian Only Lighting Cross Section

SPECIAL LIGHTING DISTRICTS

- There is a rich history of street lighting in Salt Lake City that has established Special Lighting Districts with unique street lighting character. Areas like Downtown and Sugarhouse District have unique historic street lighting that with a combination of both street and pedestrian lights mounted on the same light pole. As Salt Lake City evolves, new Special Lighting Districts may be desired to create and enhance a unique sense of place. Any new Special Lighting Districts must be coordinated with Salt Lake City to determine the ownership and maintenance agreements, and must follow the lighting strategies and lighting criteria established in this Street Lighting Master Plan.

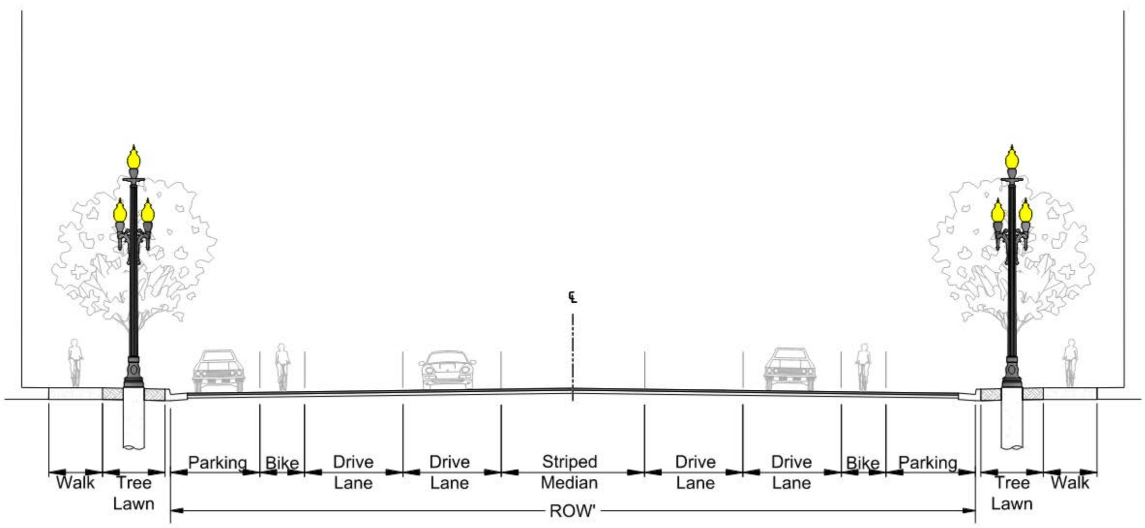


Figure 19: Cactus Lights Cross Section

INTERSECTION LIGHTING

- Proper lighting at intersections is critical for vehicle and pedestrian safety throughout the entire city.
- Intersection lighting is the minimum standard throughout the city.
- Intersection lighting encompasses the roadway after the stop bar as well as any painted crosswalks.
- See Intersection & Crosswalk Lighting for layout and spacing criteria.

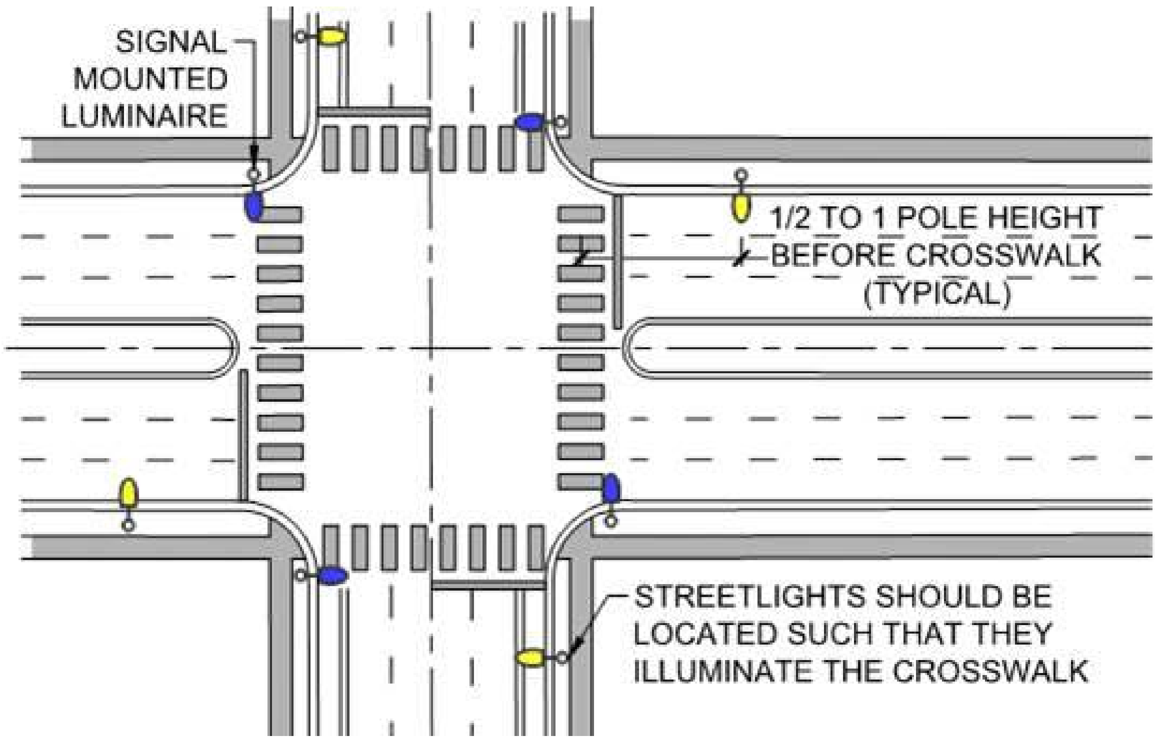


Figure 20: Intersection Lighting Plan

VERTICAL ILLUMINATION IN CROSSWALKS

- Proper crosswalk lighting in high traffic areas, commercial corridors, will support a safer and more pedestrian friendly city.
- Lighting in the vertical plane will increase visibility in crosswalks and help to reduce vehicle-pedestrian accidents.
- See Intersection & Crosswalk Lighting for layout and spacing criteria.

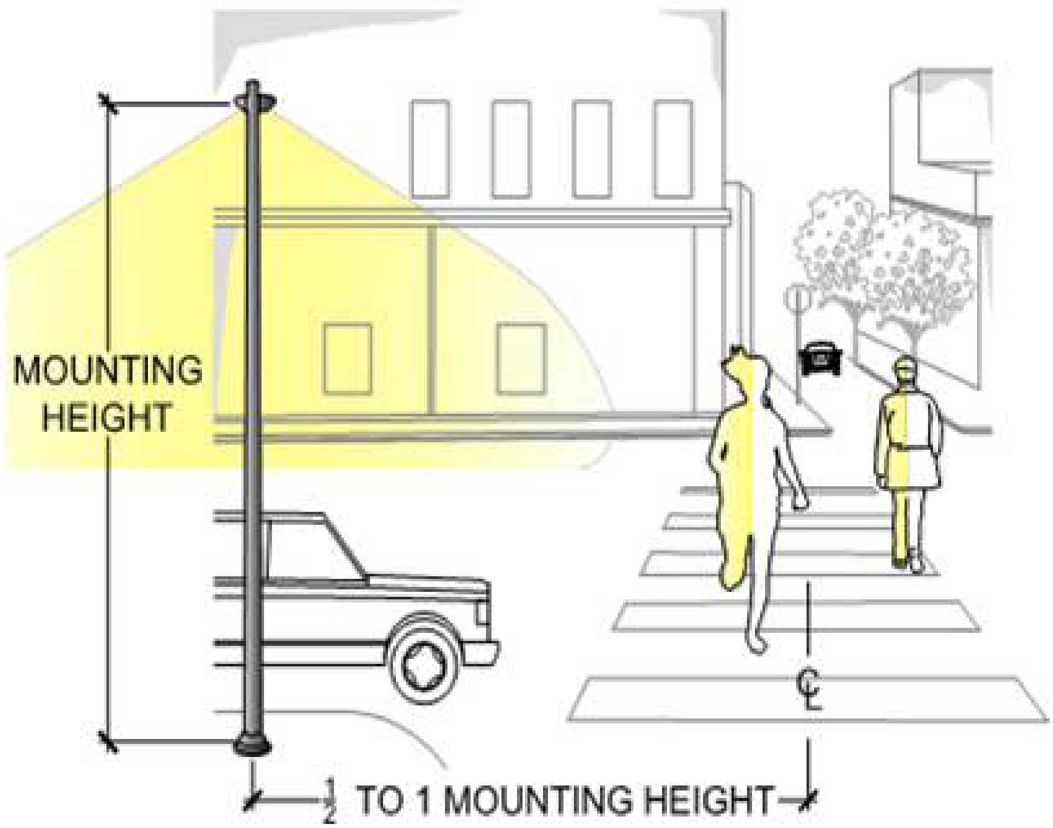


Figure 21: Crosswalk Lighting

BUS STOP

- Uncovered bus stops should be lit by a street luminaire positioned 1/2 to 1 mounting height from the bus stop in the direction of oncoming traffic.
- Bus shelters with integrated lights should provide vertical illumination to aid in facial recognition. Street lights in close proximity increase ambient light and visual comfort.
- See Volume 2 for additional information.

ENVIRONMENTALLY PROTECTED AREAS

The Salt Lake Valley is not only home to a bustling urban city but is also home to diverse and vulnerable wildlife populations and sensitive Dark Sky Areas. Salt Lake City recognizes the impacts that street lighting can have on these sensitive areas and wants to minimize the negative effects of street lighting at night. The map below highlights environmentally sensitive areas where the following lighting characteristics should be used:

- Color Temperature (CCT) no higher than 2200K,
- All lights should have increase backlight control to reduce the amount of spill light
- All lights should have zero uplight.

To read more on the impacts of light at night within the Salt Lake Valley, reference Appendix D: Nocturnal Infrastructure for Ecological Health.

IMPLEMENTATION OF UPGRADED LIGHTING

When deciding which Lighting Layout Strategy to use at various locations throughout the city, the adjacent land use is a critical factor in determining nighttime pedestrian activity. Although there are many different zoning designations in Salt Lake City, this master plan consolidates land uses into seven different categories: Commercial, Office Park, Downtown, Industrial, Multi-Family Residential, Single Family Residential, and Open Space. The different adjacent land uses throughout the city and more information on determining adjacent land use can be found in Volume 2.

Each adjacent land use has different primary considerations that determine lighting strategy and criteria. The most critical of these considerations is pedestrian and vehicle volume during nighttime hours. Areas of higher volume at night, such as Downtown and Commercial, require additional lighting, whereas industrial areas do not see the same traffic volumes during dark hours. This Master Plan also strives to be environmentally responsible, and balances vehicle and pedestrian safety with environmentally protective actions based on adjacent land use. The table below shows the main considerations, environmentally protective actions, max CCT, and lighting strategies for each adjacent land use.

TABLE 5: LIGHTING LAYOUT STRATEGY BY LAND USE

ADJACENT LAND USE	MAIN CONSIDERATIONS	ENVIRONMENTALLY PROTECTIVE ACTIONS	MAX CCT*	LIGHTING STRATEGIES
Commercial	• Diverse Land Use with High, Medium, and Low Pedestrian and Vehicle Activity During Night Hours	• Adaptive Dimming	• 3000K	• All Lighting Strategies Possible to Safely and Appropriately Light the Streets and Sidewalks.
Office Park	• Low Pedestrian Conflict at Night • Overlap with Environmentally Protected Areas	• Lower CCT • Adaptive Dimming	• 3000K	• Non-Continuous Street Lighting • Possible Non-Continuous Pedestrian Lighting
Downtown	• High and Medium Pedestrian and Vehicle Activity During Night Hours • Historic Character using Cactus Pole Lights	• Adaptive Dimming	• 3000K	• Continuous Street and Pedestrian Lighting
Industrial	• Low Pedestrian Conflict at Night • Environmental Concerns	• Lower CCT • Adaptive Dimming	• 2200K	• Street Lighting at Intersections Only
Multifamily Residential	• Pedestrian Safety • Representing the Character of the Area	• Minimizing Light Trespass • Controlling Spectrum • Adaptive Dimming	• 3000K (Arterial) • 2700K (Collector/ Local)	• Continuous and Non-Continuous Street Lighting • Continuous and Non-Continuous Pedestrian Lighting
Single Family	• Pedestrian Safety • Representing the Character of the Area	• Minimizing Light Trespass • Controlling Spectrum • Adaptive Dimming	• 3000K (Arterial) • 2700K (Collector Local)	• Continuous and Non-Continuous Street Lighting • Continuous and Non-Continuous Pedestrian Lighting
Open Space	• Environmental Concerns	• Minimizing Light Trespass • Controlling Spectrum • Adaptive Dimming	• 2200K	• Non-Continuous Street Lighting • Street Lighting at Intersections Only

**Max CCT to be 2000K in Environmentally Sensitive Areas.*

STREET LIGHTING EQUIPMENT AND TECHNOLOGY

When future improvements are made to the lighting throughout Salt Lake City, the lighting equipment selected should reflect the principles established by the Guideposts of Safety, Character and Responsibility. New equipment should match or enhance the character of the area, while also safely and responsible lighting the area.

This Street Lighting Master Plan places an increased priority on responsible lighting by using luminaires that reduce wasted light to sky glow and light trespass, and have the highest levels of energy efficiency. Future luminaires installed in the city will all be fully shielded LED lights with no light directed upward from the light source, understanding that there is a minimal allowance for reflected uplight from post-top style luminaires. As existing luminaires are upgraded to LED and new projects are constructed, the City will become a safer place for pedestrians and commuters. New pedestrian lighting will better illuminate sidewalks and crosswalks, while all new lights will reduce glare and improve nighttime visibility.

As these upgrades are being made to safer and more responsible luminaires, the character of the new lights should also match the character of the area. The lighting equipment installed at a particular site will depend on the character of the site and the adjacent land use. Precedent character, such as Downtown Cactus Poles or Sugarhouse Teardrop luminaires, will be upgraded to similar style of luminaire that reduces uplight and light trespass onto adjacent private property.

TABLE 6: RECOMMENDED LUMINARIES BY LAND USE					
	CACTUS POLE	TEAR DROP	COBRA HEAD	PEDESTRIAN ACORN	PEDESTRIAN ARM MOUNT
ADJACENT LAND USE					
Commercial	N/A	S. Temple State Street Sugarhouse BD	Base Level	N/A	Non-Continuous or N/A
Office Park	N/A	N/A	Base Level	N/A	Non-Continuous
Downtown	Downtown Historic	S. Temple State Street Sugarhouse BD	Base Level	N/A	Continuous or Non-Continuous
Industrial	N/A	N/A	Base Level	N/A	N/A
Multi-Family Residential	N/A	N/A	Intersection & Mid-Block or Intersection Only	Rose Park	Continuous or Non-Continuous
Single Family Residential	N/A	N/A	Intersection & Mid-Block or Intersection Only	Rose Park	Continuous or Non-Continuous
Open Space	N/A	N/A	Intersection & Mid-Block or Intersection Only	N/A	N/A

Luminaires (Style, Finish Color, Lumens, Distribution, CCT, CRI, BUG Rating, Shielding, Dimming Driver (0-10V, DALI), ANSI 7-Pin Receptacle, Integral Wireless Dimming Node)

Light Standards (Pole, Arms, Base, Finish Color, Banner Arms, Holiday Receptacles, Planter Arms, Traffic Signs, ANSI 7-Pin Receptacle (alt location))

Lighting Controls (Adaptive Dimming, Maintenance Reporting, Asset Management)

Smart City Devices (4G/5G Small Cell, Security Cameras, Air Quality Sensors, Smart Parking, Speakers, Gun Shot Detection, EV Charging Stations, Traffic Monitoring, Noise Monitoring

LIGHTING IMPROVEMENTS COMPLEXITY & COST

Throughout Salt Lake City, there are various existing lighting conditions, which results in lighting improvement projects with different levels of complexity and cost that range from minimal improvements, such as 1-for-1 replacements, to comprehensive improvements, such as complete lighting redesign. The complexity and cost to improve the lighting in certain areas will depend on the existing lighting conditions, location within the city, and the need for improved lighting. The City should evaluate each site and determine which level of improvements need to be made.

MINIMAL: 1-FOR-1 REPLACEMENTS

The most cost effective and quickest way to improve the lighting is 1-for-1 replacements. Salt Lake City has already begun the process for upgrading old HPS lights to new LEDs. This should be and has been implemented in areas that already have acceptable existing lighting layouts and where street lighting sufficiently illuminates the roadway and adjacent sidewalks. 1-for-1 replacements from HPS to LED will lead to lower life cycle costs through reduced energy and maintenance. When upgrading to LED luminaires, adjacent land use must be considered. 1-for-1 replacement luminaires should reflect the character of the area, while also maintaining consistent light levels and color temperature appropriate to the site.

SUPPLEMENTAL:

Additional street and pedestrian lighting may be required where the existing lighting layout does not sufficiently light the street or sidewalk. Additional street lighting may be needed if existing lights are spaced too far apart to uniformly light the roadway, or if there is no street lighting at all. Additional pedestrian lights may be needed when there is a large park strip between the sidewalk and the streetlights, where there is excessive shadowing from trees, or in areas where pedestrian lights are desired. See Volume 2 on recommendations on additional pedestrian lighting.

COMPREHENSIVE:

Comprehensive improvements to the current conditions call for complete lighting redesign. This should be considered in areas of the City where lighting redesign is required to meet requirements in the Lighting Warrants Table. Comprehensive improvements will need to be done on streets where new continuous or non-continuous street or pedestrian lighting is required. Streets without any lighting will also require comprehensive improvements and should comply with the lighting requirements in the lighting warrants table.

PRIORITIZING LIGHTING IMPROVEMENTS

Evaluating where lighting improvements should be made, and which projects should be prioritized can be a difficult process. The purpose of this section is to help provide guidance when deciding where and when lighting improvements should be made.

Areas that are currently underserved by the existing lighting and are adjacent to “High Priority Conflict Zones” should be the first to be upgraded. The more “High Priority Conflict Zones” that an underserved area is adjacent to, the higher priority it should be to improve the lighting. If an underserved area is not adjacent to any “High Priority Conflict Zones” the City should get public opinion from residents in the neighborhood to determine is upgraded or additional lighting is desired.

AREAS UNDERSERVED BY STREET LIGHTING

As seen in the lighting density map in Figure 3 on page 24, there are neighborhoods and areas of the city currently underserved by street lighting. Public outreach is required in these areas to identify neighborhood interest in upgrading lighting in these areas, particularly for pedestrians.

Neighborhood outreach will allow interested residents to review the options identified in the lighting matrix and make an informed decision for their area.

HIGH PRIORITY CONFLICT AREAS

High Priority Conflict Areas are locations throughout the city where there is typically increased pedestrian or bicycle activity. If a location underserved by the existing lighting and is near a High Priority Conflict Area(s), that site should be prioritized. Maps showing these areas are shown below. A site with more High Priority Conflict Areas should become a priority area for implementation.

School Zones

Streets within a one-block radius of all schools within the Salt Lake Valley should be lighted according to the appropriate adjacent land use and increased pedestrian conflict level as a result of being close to a school. If a school falls within a neighborhood where minimum lighting is desired by residents, additional lighting for pedestrian safety should be installed. Lighting near school zones should ensure that crosswalks are sufficiently lighted as well as all entrances and exits to the campus.

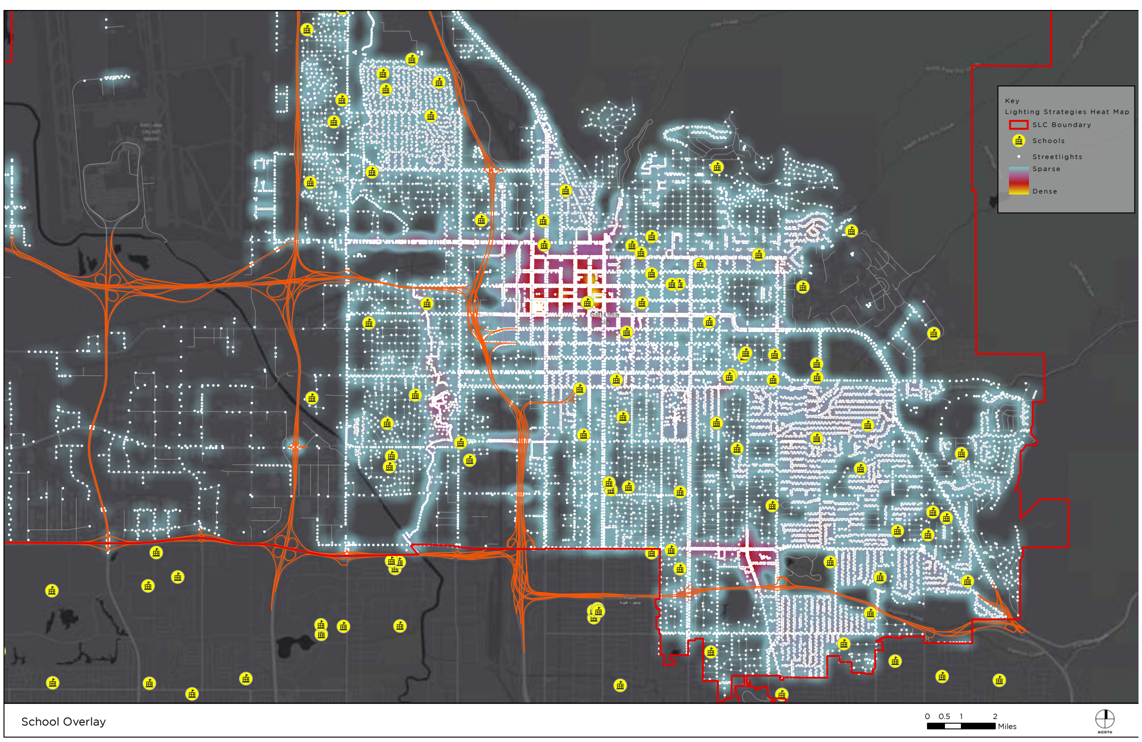


Figure 22: School Locations

Bus Stops

Lighting near bus stops should also be prioritized within the city. If a bus stop is not already sufficiently lighted, placing one light on the approach side of an uncovered bus stop one half to one mounting height is required. See Volume 2 for more information on covered and uncovered bus stops.

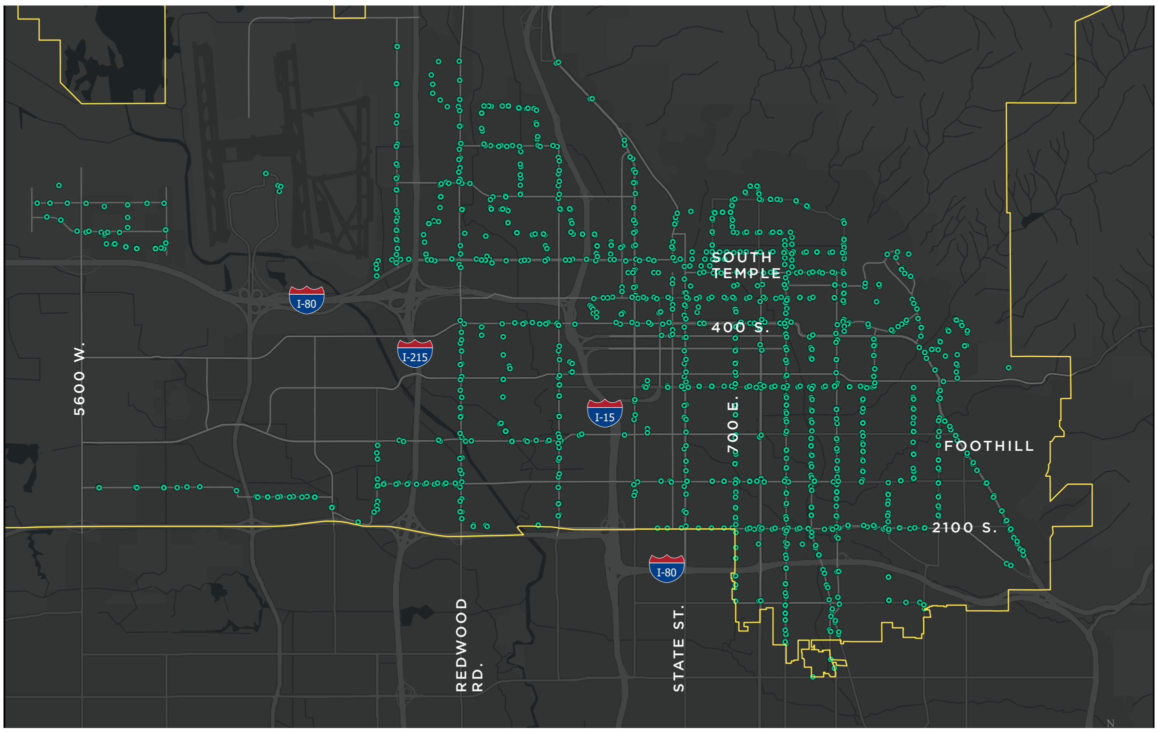


Figure 23: Bus Stops

Transit Stations

Transit stations within the Salt Lake Valley are lighted by UTA and are not within the jurisdiction on Salt Lake City. However, these transit stations result in higher pedestrian and vehicle traffic volume on adjacent streets. Adjacent streets should be lighted according to the appropriate adjacent land use and the increased pedestrian volume as a result of being close to a transit station.

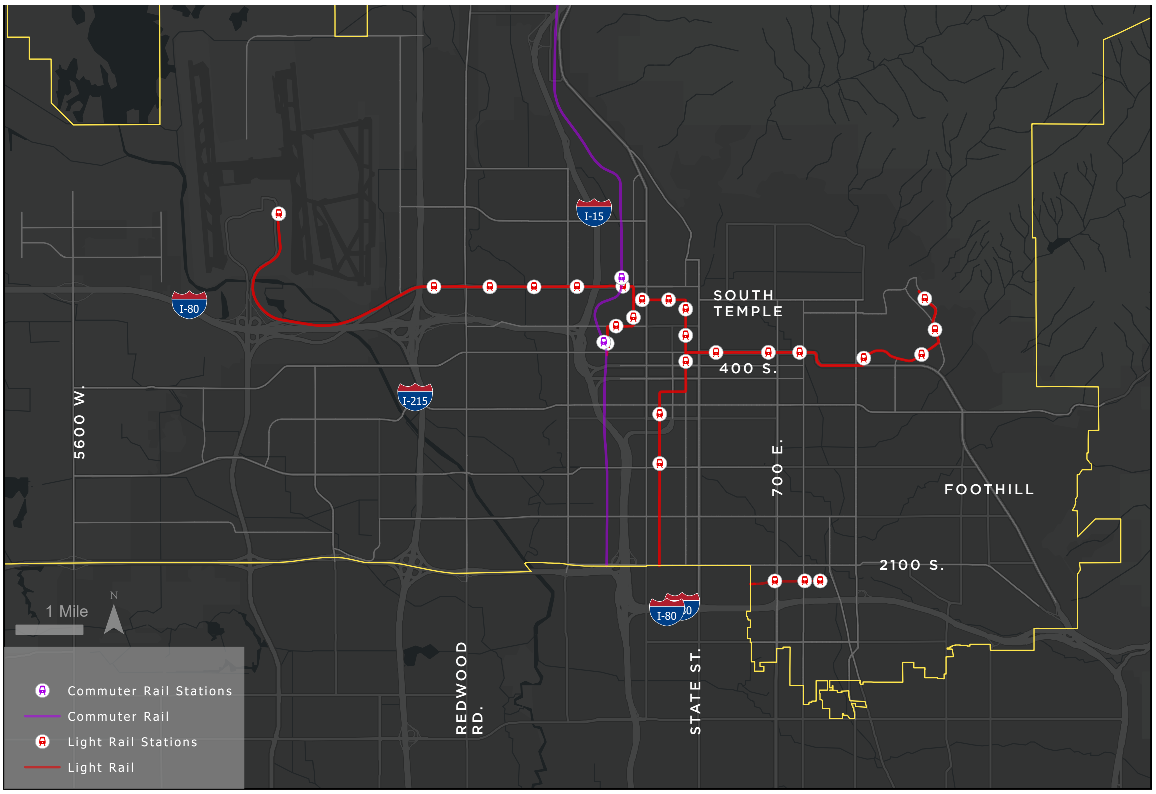


Figure 24: Transit Station Locations

Neighborhood Byways

Salt Lake City is working on encouraging more biking and walking in the City by creating pedestrian centric streets called neighborhood byways. The streets should be continuous lighting with pedestrian lights to help encourage more pedestrian travel.

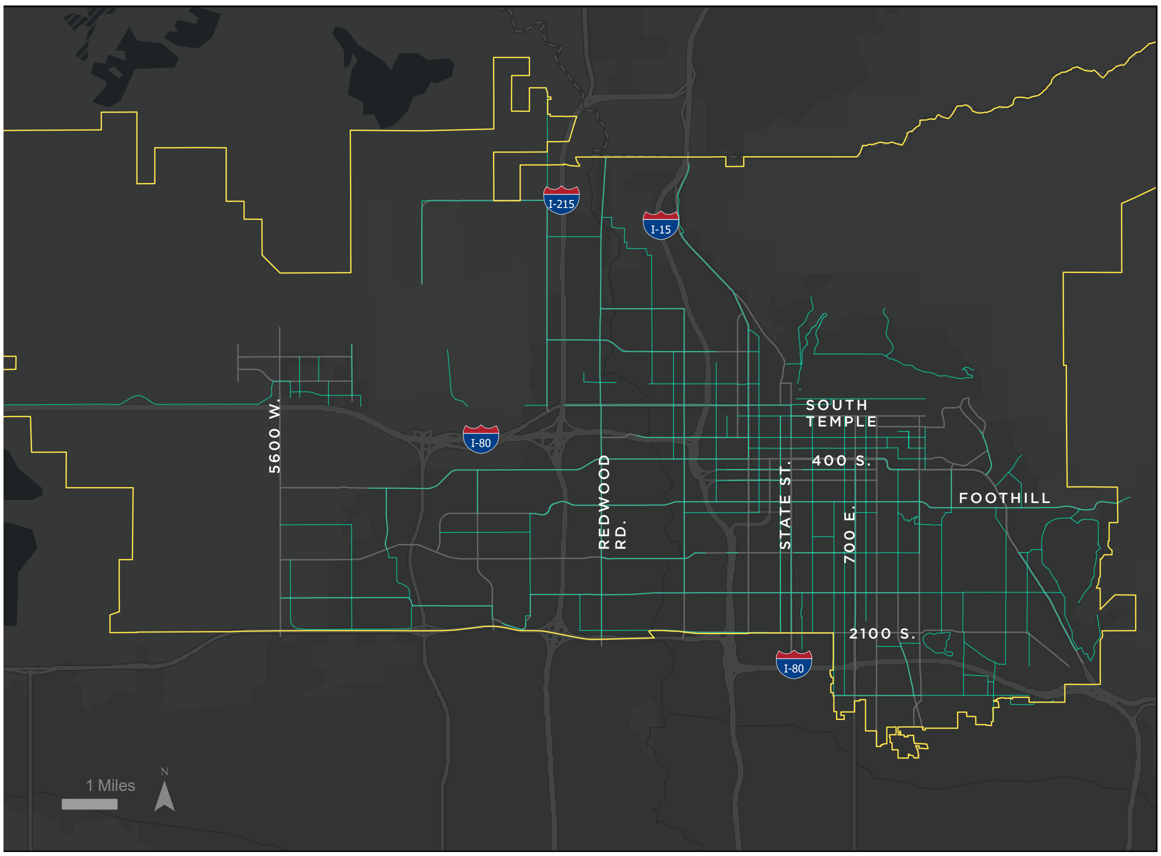


Figure 25: Neighborhood Byways Locations

PRIORITIZING 1-FOR-1 LIGHTING IMPROVEMENTS

For areas where current street lighting is adequate in terms of pole type and head placement and type, one-for-one replacements from HPS to LEDs is the appropriate response to improve light quality and achieve energy savings. The City is currently working toward upgrading all street lights to LED, but should prioritize locations with existing HPS lights, are well as locations where LED lights are glaring or obtrusive.

Streets with Existing High-Pressure Sodium Street Lights

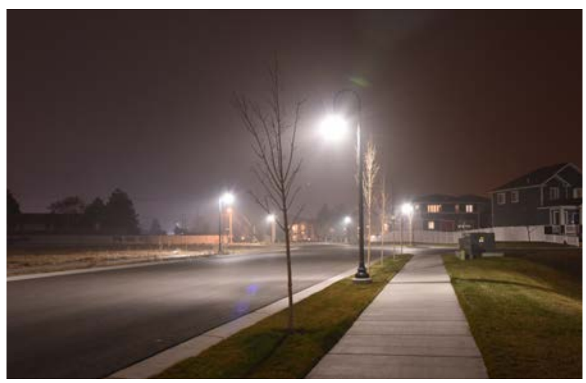
The City should prioritize upgrading existing HPS lights to new LEDs with increased glare control and dimming capabilities. More information on selecting the proper replacement luminaire can be found in Volume 2.

Reduce Glare and Light Trespass

Some LED lights within Salt Lake City are too bright and can cause glare and light trespass. These lights should be replaced with new LEDs that have better glare control and are compatible with the City's lighting control system. Additionally, some LEDs within the city have a higher color temperature than 3000K and should be replaced by a luminaire with appropriate CCT based on adjacent land use.

Reduce Light Pollution from Existing Decorative Lights

Converting the existing Cactus Pole lights to LED lights with "U0" uplight rating will significantly reduce the amount of sky glow and light pollution around Salt Lake City.



EXISTING CACTUS POLE LIGHTS

UPGRADED CACTUS POLE LIGHTS

DESCRIPTION OF VOLUME 2: TECHNICAL LIGHTING DEVELOPMENT GUIDE

Light Terms and Definition

The following terms are used throughout this Master Plan and in the lighting industry. Understanding these terms is essential to properly understanding and implementing this Lighting Master Plan.

Lighting Term	Unit	Definition
Backlight, Uplight, and Glare (BUG) Ratings	B0 – B5 U0 – U5 G0 – G5	Luminaire Classification System for Outdoor Luminaires per IES TM-15 describing the amount of uplight, backlight and glare. Lower numbers in each classification are associated with lower impacts. • B = backlight, or the light directed behind the luminaire. • U = uplight, or the light directed above the horizontal plane of the luminaire. • G = glare, or the amount of light emitted from the luminaire at angles known to cause glare.
Color Rendering Index (CRI)	0 - 100	The color rendering index (CRI) is a developed metric on a scale of 0 to 100, to communicate the ability of the light to render an object's natural color
Continuous Lighting		A street lighting system made up of regularly spaced luminaires along the street. Criteria typically defines minimum and maximum illuminance or luminance values and overall uniformity along the lighted area.
Correlated Color Temperature (CCT)	Kelvin (K)	The color appearance of the light emitted by a lamp. The CCT rating for a lamp is a general "warmth" or "coolness" measure of its appearance. Fire has a CCT of 1850K and daylight is 6000K.
Glare		The visual sensation created by luminance (or brightness) that is significantly higher than the surrounding luminance that the eyes are adapted to, causing annoyance, discomfort, or loss in visual performance and visibility (disability glare).
Illuminance	Footcandle (Fc)	The density of light (lumens per square foot) falling onto a surface. Commonly measured in the horizontal and vertical planes.
Illuminating Engineering Society (IES)		The IES strives to improve the lighted environment by publishing recommended practices to guide lighting designers, architects, engineers, sales professionals, and researchers. The IES's *The Lighting Handbook* and *Recommended Practices* are the recognized authoritative reference on the science and application of lighting.
Legacy Light Source		All non-LED light sources: incandescent, halogen, high pressure sodium, low pressure sodium, induction, and fluorescent.
Life Cycle Cost		An economic analysis of an investment that covers all the costs and benefits over the expected life of the equipment or system. Unlike a simple payback analysis, it accounts for maintenance and energy even after the system is paid for with projected savings.

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DRAFT SURVEY

9/5/2018

SURVEY QUESTIONS:

1. Place pin on map in general location of where you live or work.
   - *Provide map with pin location ability*
2. Does the street lighting around this location allow you to feel safe while walking outside during dark hours of the day? *(Mark One)*
   - Yes
   - No
3. If the pin located reflects where you live, does the current street lighting interfere with your sleeping habits? *(Mark One)*
   - Yes
   - No
   - N/A (Pin does not reflect location of my home)
4. What is your impression of the light level on the street you live on? *(the response will change the color of the pin)*
   - Comfortable *(pin color: green)*
   - Too Dark *(pin color: blue)*
   - Too Bright *(pin color: red)*
5. Do you like the color of the light source?
   - Yes
   - No
6. Does the light source create too much glare?
   - Yes
   - No
7. Please provide any additional comments:
   - Write in additional comments

ARCHITECTURE • LANDSCAPE ARCHITECTURE • INTERIOR DESIGN • PLANNING

GSBS ARCHITECTS

AGENDA

PROJECT #: 2018.075
PROJECT: SLC Street Lighting Master Plan
NEXT MEETING: *Tentative: Sept 19, 2018*

MEETING #: 2
MEETING DATE: September 5, 2018
ISSUED BY: L. Smith | GSBS Architects

Revised post meeting

ATTENDEES:

X	Jesse Allen	X	Brad Stewart		
X	Lauren Smith		Jesse Stewart		
	Christine Richmond				
X	Dane Sanders				
X	Riley Rose				
X	Jason Brown				
X	David Pearson				

AGENDA ITEMS:

1. Review Public Outreach Strategy
   - Advisory Committee Members
     - District 1 Citizen Representative *(identified by District Representative)*
     - District 2 Citizen Representative *(identified by District Representative)*
     - District 3 Citizen Representative *(identified by District Representative)*
     - District 4 Citizen Representative *(identified by District Representative)*
     - District 5 Citizen Representative *(identified by District Representative)*
     - District 6 Citizen Representative *(identified by District Representative)*
     - District 7 Citizen Representative *(identified by District Representative)*
     - Mayor's Office Representative
     - Public Utilities Representative

   - Technical Committee Members
     - SLC Engineering, Sean Fyfe
     - SLC Transportation, Jon Larsen
     - SLC Planning, Doug Dansie
     - SLC Planning, Molly Robinson
     - SLC Parks + Public Lands, Nancy Monteith
     - SLC Fire
     - SLC Police

   - Stakeholder Groups (Individual Groups + representatives representing each group)
     Draft List

     - Downtown Alliance + Business Districts (9th and 9th, Sugarhouse)
     - Environmental (Dark Sky, Tracy Aviary, Audubon)
     - Multi-modal (UTA, Bicycle Transit)
     - School District
     - Inland Port, NW Quadrant

   - Draft Public Survey
     - *See Attachment 'DRAFT SURVEY'*

375 WEST 200 SOUTH
SALT LAKE CITY, UT 84101
P 801.521.8600
F 801.521.7913

7291 GLENVIEW DRIVE
FORT WORTH, TX 76180
P 817.589.1722
F 817.595.2916

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2. Review Proposed Project Schedule
    - *See Attachment*
3. Status of Contract
    - Updates
4. Next Steps
    - SLC Public Utilities to review pass along revised Draft Survey for review
    - GSBS and Clanton to review and revise scope and fee – get to Public Utilities early next week
    - Brad to send GSBS and Clanton contact for Open City Hall to work together on upload process and capabilities of public survey

OTHER INFORMATION:

ARCHITECTURE • LANDSCAPE ARCHITECTURE • INTERIOR DESIGN • PLANNING

GSBS ARCHITECTS

MEETING NOTES

PROJECT #: 2018.075
PROJECT: SLC Street Lighting Master Plan
NEXT MEETING: *TBD*

MEETING #: 9
MEETING DATE: April 26, 2019
ISSUED BY: L. Smith | GSBS Architects

These notes represent the general understanding of the author concerning the topics covered. If there are errors or misrepresentations, please inform the author in writing and adjustments will be made with the next issuance of notes.

ATTENDEES:

X	Jesse Allen, GSBS Architects		Laura Briefer, Public Utilities
X	Lauren Smith, GSBS Architects		Holley Mullen, Public Utilities
X	Dane Sanders, Clanton and Associates	X	Katie, Clanton and Associates
X	Riley Rose, Clanton and Associates	X	Technical Committee
X	David Pearson, Public Utilities	X	Annette, Planning
X	Jesse Stewart, Public Utilities	X	Cooper, Police
	Brad Stewart, Public Utilities	X	Ron Fife, Fire Department
X	Jack, SLC Engineering	X	Peter, Sustainability

NEW BUSINESS:

1. Goal:
    - How to spend the budget within
        - The next 5-10 years
        - What is needed to budget and how to prioritize

2. Planning (Annette filling in for Mayara)
    - Design and color of the streetlights fit within the neighborhood
        - Historic Districts
        - Rose Park
        - Poplar Grove
    - Color meaning: the LED color temperature and the color of the poles/luminaries
    - Day time aesthetics
        - No planning master plans include streetlights currently
        - Need to double check to make sure if there is any overlap
    - Conflict between districts if they do not get the same thing?
        - Historic districts are treated completely differently than others
        - Guidelines for street lighting in historic districts
    - Have the street lighting master plan acknowledge the design guidelines
    - Review the historic districts and guidelines
    - Other districts:
        - Downtown district
    - Districts vs. neighborhoods
        - Rose park and poplar grove are known for their street trees
        - These should be on the website
        - Maybe already in GIS
    - Make sure to get those layers in GIS

3. Engineering
    - What existing programmatic controls does the city have that protect the existing streetlight utility/ power supply?
    - As more lights get installed, what can be done to make sure that the power supply is protected?
    - Subsurface in the right of way is getting really crowded

375 WEST 200 SOUTH
SALT LAKE CITY, UT 84101
P 801.521.8600

7291 GLENVIEW DRIVE
FORT WORTH, TX 76180
P 817.589.1722

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- Currently the lines are not in Blue Stake
- Is it practical/room for improvement on location of lines?
- As time/budget allows, possibility to move the lines into blue stake
  - This would keep survey crews busy for about 2 years
  - This would lie more in implementation vs. master plan
  - Important to note in recommendations of how to move forward

4. Sustainability
   - Energy 2040
     - 80% reduction in our Green House Gases by 2040 (community wide for the whole city)
     - 50% renewable energy goal by 2020
     - Baseline is 2009
   - Updating Climate response plans
   - Solar Street Light just received
     - On a cul-de-sac off 2700 S testing
   - Solar Roadways
     - Lot of progress in Europe and a company in Idaho
   - Slowed wholesale replacements until this master plan is complete
     - Replacing as needed but not overhaul now
   - What % of the City's energy does Street light make up?
   - Strategies:
     - LED obvious
     - Dimming
     - Lumens/watt
   - Technology, part of our perception
   - Dimmable LED's at 17th and 17th
     - Maybe run a test program and dim the lights down to 50% for a week then possibly dim down to 25%
   - Dark Sky

5. Police
   - Evidence Preservation
   - Preventing Crime
   - Controlling Crime
   - Smart Lighting
     - Help a lot with tactical teams to go into a standoff – control the lighting on that block would be immensely important and helpful
     - Dimming down and making brighter both could be helpful
     - Dave can give Police and Fire log in to Smart Lights to be able to control on their own when needed
     - Gunshot detection
     - Lead the fire truck
     - Citizens are asking for it too
   - Opportunities
     - Brighten up when Jazz game lets out
     - Lower the lights during snowstorm
     - Over design for brighter level and dim?
     - Or overdrive the LEDs for short period of time during when you want them up
       - What are those cost implications?
   - Lighting for the sidewalks in different neighborhoods
   - Support LED because of the color rendering for victims and witnesses to identify colors of cars and suspects
   - Trees block a lot of the light in different neighborhoods
   - Even/consistent lighting throughout neighborhoods
   - Lots of midblock lights are blocked by the trees
   - Acorn lights - because of the way they light
     - A lot of glare
     - The way it glares it creates a blind spot especially right at the pole
   - Stop the light right at the back of the sidewalk
     - Glare makes it nearly impossible to see anything from a camera
   - Distribution of light

6. Fire
   - Inclusive with police
   - Uneven light when responding can lead to inability to see pedestrians and cars

    - Even light help the drivers see vehicle and pedestrians
    - Evening lighting on the street and approach at a minimum to get where they need to be without obstruction
  - On seen
    - Visualizing the addresses
    - Ongoing issue
    - Maybe hard to address with street lighting
    - Able to illuminate the seen if needed see obstacles
    - People step in holes because they cannot see where they are going,
    - Focused on the issue they are there to solve

End of meeting notes.

Existing Street Lighting Conditions

Salt Lake City, Utah

Executive Summary

Salt Lake City requested an evaluation of the existing street lighting conditions and a Master Plan to aid in transitioning the remainder of the street lighting from a high pressure sodium system to an LED system and implement a lighting control system, with the intent to improve visibility and aesthetics while reducing energy and maintenance. The Master Plan develops new street lighting standards for retrofit and new construction. To obtain a comprehensive understanding of the existing lighting, Clanton & Associates surveyed seventeen locations within the city, conducted nighttime surveys, and calculated the light levels along primary arterial, minor arterial, collector and local streets. From these evaluations, existing condition templates were created to aid the city in prioritizing improvement areas which will influence street lighting retrofits. By enhancing the street lighting, the city will promote a higher standard of well being as well as a more comfortable place for residents and commuters.

Evaluation of Existing Lighting Conditions

In November 2018, Clanton & Associates evaluated the current lighting conditions at seventeen sites around the city that provided an understanding of the diversity of lighting conditions. The selected sites included arterial, collector and local streets with industrial, commercial, and residential areas. Both horizontal and vertical illuminance[1]measurements were taken along the sidewalks at each site. Luminance[2] measurements were also taken to provide an understanding of surrounding surface brightness. These measured light levels were used to compare the existing light levels to the light level recommendations by the Illuminating Engineering Society (IES). Clanton & Associates also took high-dynamic-range (HDR) images as a visual representation of the perceived nighttime experience. Along with the lighting measurements, the Advisory and Technical Committees completed a subjective survey assessing the lighted environment at each site. The survey evaluated how each participant felt about the lighting strategies and overall light levels at each site as well as how comfortable participants were at the sites. The survey results will be compared to existing light levels and lighting criteria to guide the development of the Street Lighting Master Plan and the lighting standards included in it. The site evaluations, and lighting measurements can be found in this report.

Street Lighting Levels

To understand the street lighting throughout the entire city, Clanton & Associates will calculate light levels on arterial, collector and residential streets. These calculations will be compared to existing street lighting GIS data to determine how well roadways were lighted. Street blocks will be categorized into three levels of acceptability based on the calculations, lamp wattage, street type, luminaire spacing, and by comparing measure lighting levels to IES standards.

- **Acceptable**: Streets that met the lighting standards based on street classification with existing luminaire spacing. These areas would not require any lighting improvements beyond the LED retrofit assuming all current luminaires are operating properly.
- **Moderately Acceptable**: Streets that do not meet lighting standards based on street classification with existing luminaire spacing. Typically, these are blocks that have relatively small dark spaces between poles and would require minor improvements in order to meet lighting standards.
- **Poor**: Streets that have very low, or no, street lighting. These are blocks that typically do not have enough existing street lights and will most likely require significant investment in new lighting and electrical infrastructure to meet lighting standards.

Lighting Improvements

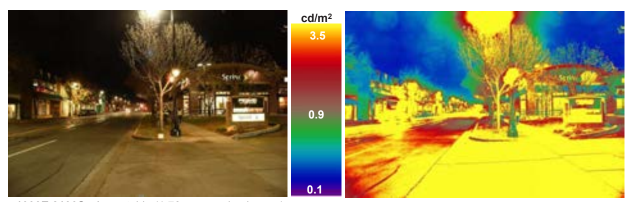
Lighting improvements in Salt Lake City will enhance lighting on arterial, collector and residential streets by classifying each street, setting standards and guidelines for street lighting retrofit and new construction projects. Well lit streets will help to reduce vehicle accidents as well as pedestrian/vehicle conflicts. Various character districts will be designated throughout the city in order to provide cohesive and quality lighting based on the surrounding environment. Vertical light levels will also be increased to enhance pedestrian and object visibility. LED luminaires consume significantly less energy and require far less maintenance than traditional lighting systems resulting in a quick return on investment.

Existing Conditions Example

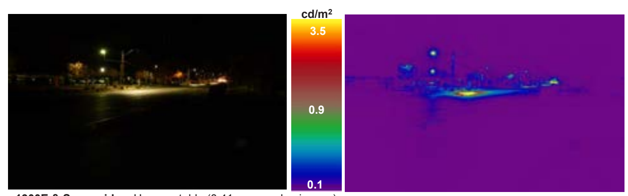
The following High Dynamic Range images (HDR) and measured illuminance levels were taken during the November 2018 site visit. An analysis of the seventeen sites surveyed can be found in this report.

Measured Illuminance Levels

Criteria	Acceptance Level	Luminance Type (cd/m^2)	Street Luminance
Arterial Street Criteria	Acceptable	Average	0.9
1000E. 2100S.	Acceptable	Average	1.76
1900S. Sunnyside	Unacceptable	Average	0.41

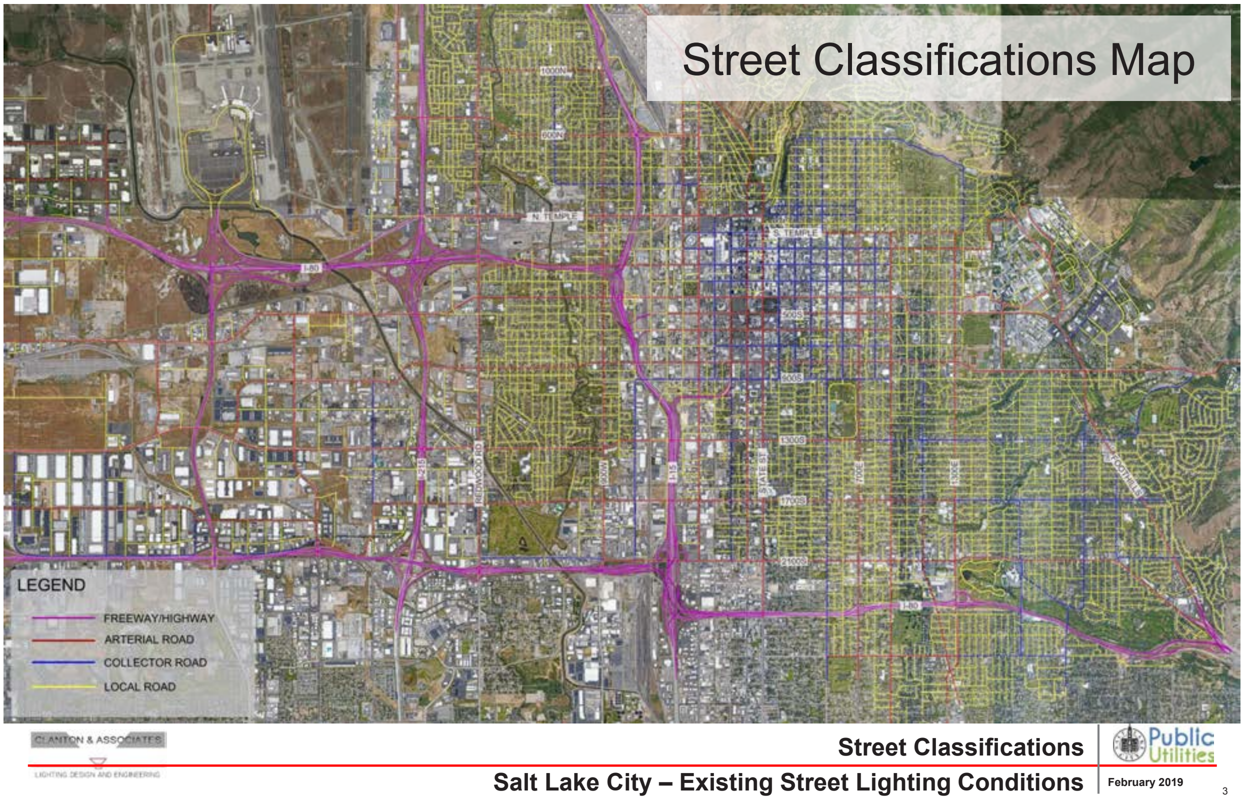


1000E 2100S– Acceptable (1.76 average luminance)



1900E & Sunnyside – Unacceptable (0.41 average luminance)

[1] Illuminance: the amount of light reaching a surface, expressed in units of footcandles [fc]
[2] Luminance: the amount of light reflected from a surface that the eye perceives, expressed in units of candela per square meter [cd/m^2]


Street Classifications Map
LEGEND
FREEWAY/HIGHWAY
ARTERIAL ROAD
COLLECTOR ROAD
LOCAL ROAD
CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING
Street Classifications
Salt Lake City – Existing Street Lighting Conditions
Public Utilities
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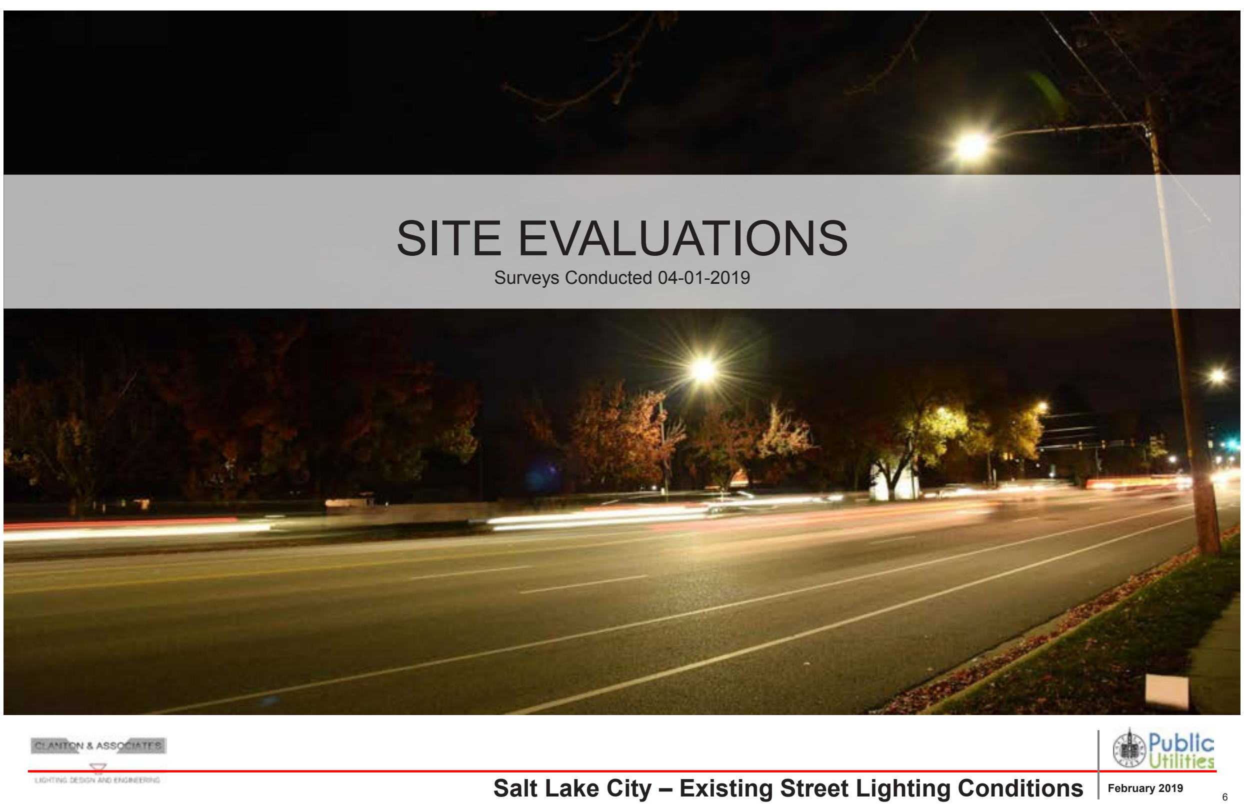
SITE EVALUATIONS
Surveys Conducted 04-01-2019
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Salt Lake City – Existing Street Lighting Conditions
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700E. Harrison Daytime Environment


700E. Harrison Nighttime Environment


700E. Harrison High-Dynamic Range

Site Observations

This Salt Lake City Street Lighting Study provides an understanding of the current street lighting in seventeen different locations throughout the city. The sites were surveyed by representatives from each of the seven council districts, as well as Salt Lake City representatives from the Police, Fire, Engineering, City Planning, Sustainability, Transportation, and Urban Forestry departments.

The sites were selected based on street type, arterial, collector, or residential, and on their surrounding environments in the city, industrial, commercial, transit or residential. The selected sites will help provide a collective understanding of the lighting and environmental conditions found throughout the city. This study and the Street Lighting Masterplan are limited to streets, sidewalks and pedestrian paths in the Public Right of Way and do not include any privately owned lighting. The seventeen sites surveyed asked about the street and sidewalk lighting conditions. Those sites included:

1. Sterling & American Beauty Dr.
2. 600N & Riverside Park
3. Redwood Road & South Temple
4. 700S & Post Street
5. 900W & Dalton Ave
6. Glendale Dr. & Navajo St
7. Jay St & 1st Ave
8. 800E & South Temple
9. 200S & Floral St
10. 650S & Main Street
11. 700E & Harrison Ave
12. 9th & 9th
13. Layton Ave & West Temple
14. 1500S & Yale
15. 19th E & Sunnyside
16. 1400E & Redondo
17. 1000E & 2100S

Each site was photographed using High Dynamic Range photography techniques and lighting measurements were recorded for the streets and sidewalks. Both horizontal and vertical illuminance (the amount of light reaching a surface) measurements were taken along the sidewalk. Luminance (the amount of light on a surface that the eye perceives) measurements were taken along the roadway to provide an understanding of roadway brightness at each site. These measured light levels were used to compare the existing light levels to the light level recommendation from the IES Recommended Practice for Roadway Lighting (RP-8-18). Clanton & Associates also took high-dynamic-range (HDR) images as a visual representation of the perceived nighttime experience. An example, of the images taken, is shown to the left.

After measurements were taken, the Advisory and Technical Committee were broken into two groups and taken on a nighttime tour of the selected sites and asked to complete a survey assessing the lighted environment. The survey was comprised of several subjective questions regarding the safety and aesthetics of each site. The survey includes, but was not limited to, the following questions:

- It would be safe to walk here, alone, during daylight hours.
- It would be safe to walk here, alone, during darkness hours.
- The light is uneven (patchy).
- The light sources are glaring.
- The lighting is poorly matched to the neighborhood.

Participants answered each question with a ranking between Strongly Agree and Strongly Disagree. The answers to each question were combined to provide an understanding of each site. Participants surveyed 11 different sites featuring arterial, collector and residential streets in industrial, commercial and residential areas.

Establishing Levels of Acceptability

Four "Levels of Acceptability" were determined from an analysis of the site observations and survey results: Excellent, Good, Moderate and Poor.

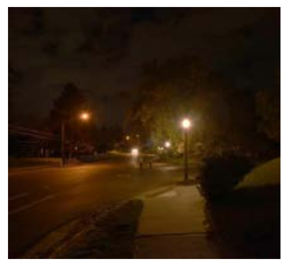
Excellent acceptability is obtained by providing sufficient and appropriate lighting on the roadway, while also providing adequate vertical illumination to allow for object detection and facial recognition. The lighting in this location will be relatively uniform, free of direct glare and properly illuminates the roadway and sidewalk.

Good acceptability indicates that the lighting in the area feels comfortable. In some cases, such as residential areas, the light level might be lower than the IES Recommended Practice but the lack of glare and shadowing from surrounding landscaping, along with some surrounding surface brightness, creates a comfortable nighttime environment without light trespass.

Moderate acceptability is often seen in locations that do not provide enough light on the roadway or on the sidewalk. The color of the light may be inconsistent and sources may be glary resulting in a uncomfortable space. Some of these sites were shadowed due to trees and lighting was not appropriately spaced.

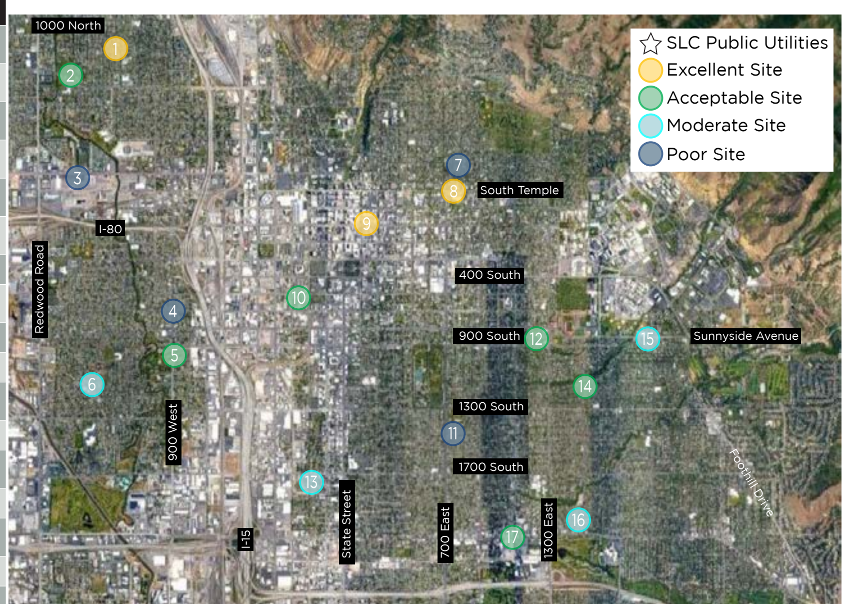
Poor acceptability occurs when the luminaires are spaced too far apart to provide adequate light levels and uniformity or there are no luminaires on the street at all. These sites included residential areas without sufficient light, industrial sites and an arterial road where lights were malfunctioning.

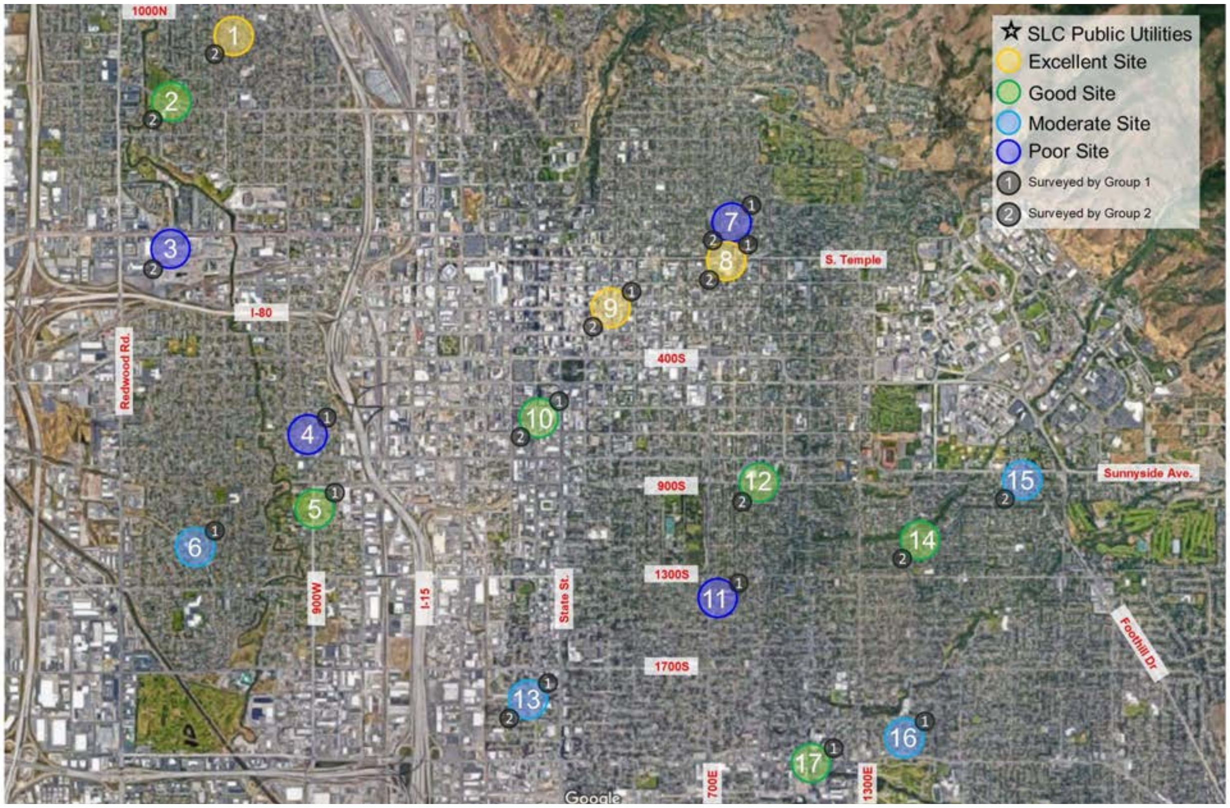
These levels of acceptability provide an understanding of the nighttime environments found throughout the city. This allows a variety of lighting improvement options to be developed. These future lighting options will enhance the nighttime safety and security around the city. Each option will focus on improving light levels, uniformity, and wayfinding while reducing glare.


Example of Good Residential Lighting

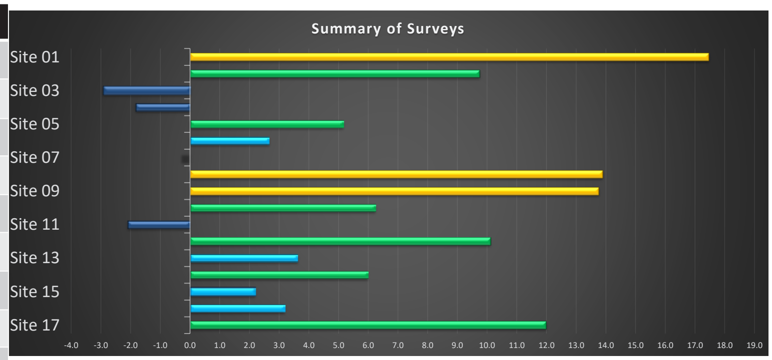

Example of Poor Residential Lighting

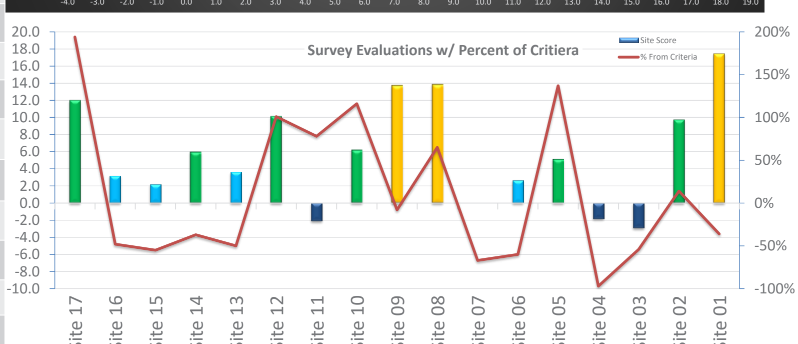
Site #	Site Name	Street Classification	Existing Lighting
1	Sterling & American Beauty Dr.	Local / Residential	Excellent
2	Riverside Park & 600 North	Arterial / Park	Acceptable
3	Redwood Rd. & South Temple	Collector / Industrial	Poor
4	700 South & Post Street	Local / Residential	Poor
5	500 West & Dalton Ave.	Arterial / Residential	Acceptable
6	Glendale Dr. & Navajo St.	Collector / Residential / Commercial	Moderate
7	J St. & 2nd Ave.	Local / Residential	Poor
8	800 East & South Temple	Arterial / Commercial	Excellent
9	200 South & Floral St.	Arterial / Commercial	Excellent
10	650 South & Main St.	Arterial / Commercial	Acceptable
11	700 East & Harrison Ave.	Arterial / Residential	Poor
12	900 East & 900 South	Arterial / Commercial	Acceptable
13	Layton Ave. & West Temple	Local / Residential	Moderate
14	1500 South & Yale	Collector / Residential	Acceptable
15	19th East & Sunnyside	Arterial / Residential / Commercial	Moderate
16	1400 East & Redando	Local / Residential	Moderate
17	1000 East & 2100 South	Arterial / Commercial	Acceptable





Site #	Site Name	Street Classification	Existing Lighting
1	Sterling & American Beauty Dr.	Local / Residential	Excellent
2	Riverside Park & 600N	Arterial / Park	Acceptable
3	Redwood Rd & South Temple	Collector / Industrial	Poor
4	700S & Post Street	Local / Residential	Poor
5	900W & Dalton Ave	Arterial / Residential	Acceptable
6	Glendale Dr. & Navajo St	Collector / Residential / Commercial	Moderate
7	J St & 2nd Ave	Local / Residential	Poor
8	800E & South Temple	Arterial / Commercial	Excellent
9	200S & Floral St	Arterial / Commercial	Excellent
10	650S & Main St	Arterial / Commercial	Acceptable
11	700E & Harrison Ave	Arterial / Residential	Poor
12	9th & 9th	Arterial / Commercial	Acceptable
13	Layton Ave & West Temple	Local / Residential	Moderate
14	1500S & Yale	Collector / Residential	Acceptable
15	19th E & Sunnyside	Arterial / Residential / Commercial	Moderate
16	1400E & Redondo	Local / Residential	Moderate
17	1000E & 2100S	Arterial / Commercial	Acceptable





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Salt Lake City – Existing Street Lighting Conditions

Public Utilities
February 2019

Site 1 : Sterling & American Beauty Dr

Local / Residential

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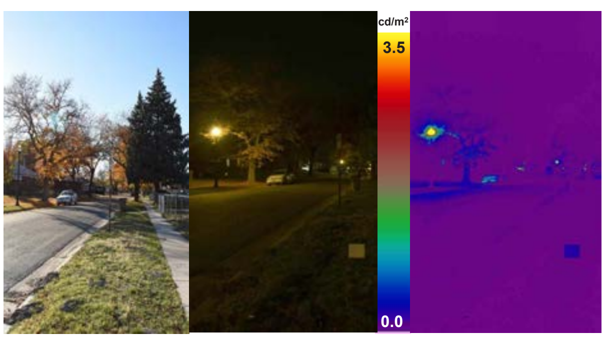
Public Utilities

Salt Lake City – Existing Street Lighting Conditions

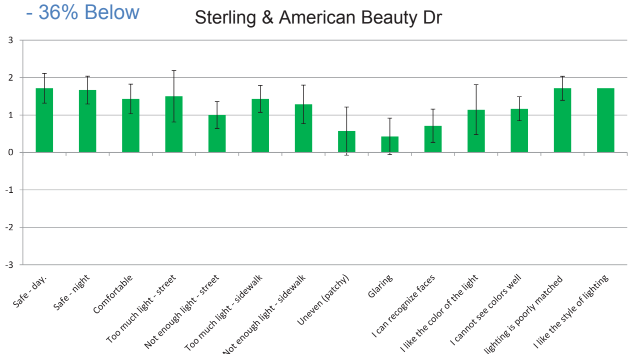
February 2019



Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
- 36% Below

Sterling & American Beauty Dr



Level of Acceptability: Excellent (Lighting Score = 17.5)
Sterling Dr is in Tier 1 of the Enhanced Lighting Program with acorn lights spaced at intersections and mid block.

Initial Site Observations
- Local Residential street in Rose Park neighborhood.
- Part of Enhanced Lighting Program Tier 1.
- Adjacent to Rose Park Elementary School

Lighting Measurements
- Street lighting does not meet criteria for a local road with a low pedestrian conflict.
- Low vertical light levels make it difficult for cars to identify pedestrians and objects in the roadway.

Participant Survey
- Participants said:
  - "Great lighting for a residential area."
  - "This is nice lighting. A model for rest of city "

		Sidewalk Illuminance (fc) Horizontal	Sidewalk Illuminance (fc) Vertical (min)	Roadway Luminance (cd/m^2)
Local Criteria Low Conflict	Average	0.4	0.1	0.3
	Ave/Min	4	-	6
Site 1	Average	0.2	0.0	0.1
	Ave/Min	5.9	-	1.9

Site 1 : Sterling & American Beauty Dr

Local / Residential

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Salt Lake City – Existing Street Lighting Conditions

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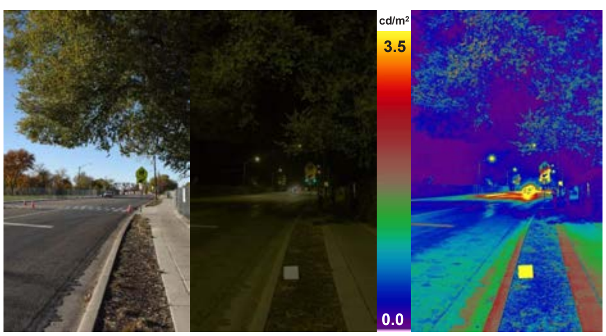
LIGHTING DESIGN AND ENGINEERING

Site 2 : Riverside Park @ 600N
Arterial / Park

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

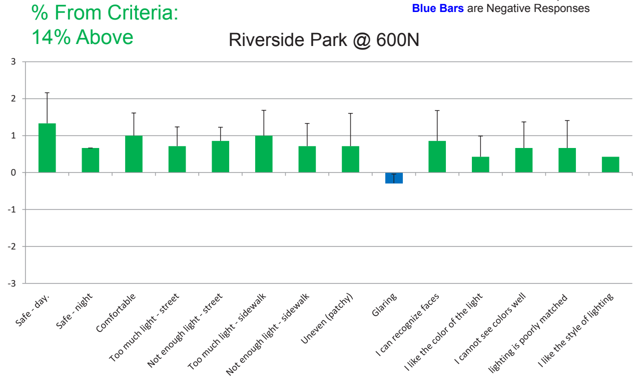
February 2019



Level of Acceptability: Acceptable (Lighting Score = 9.8)
600N is lit with LED luminaires in a staggered arrangement and meets roadway lighting criteria.

Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
14% Above



Initial Site Observations
- This is a wide arterial road with heavy traffic from commuters and shipping.
- This site is located between Riverside Park and Backman Elementary School.
- Street lights are LED and arranged in a staggered arrangement.

Lighting Measurements
- This street meets the roadway luminance criteria for an arterial street with a medium pedestrian conflict.
- Horizontal illuminance on the sidewalks meets criteria, but vertical illuminance does not.

Participant Survey
- Participants felt the amount of light was good, however the style and color does not match the neighborhood.
- Participants found the light the be slightly glaring

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Arterial Criteria Medium Conflict	Average	0.5	0.2	0.9
	Ave/Min	4	-	3
Site 2	Average	0.5	0.0	1.0
	Ave/Min	15.8	-	1.9

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Site 2 : Riverside Park @ 600N
Arterial / Park

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

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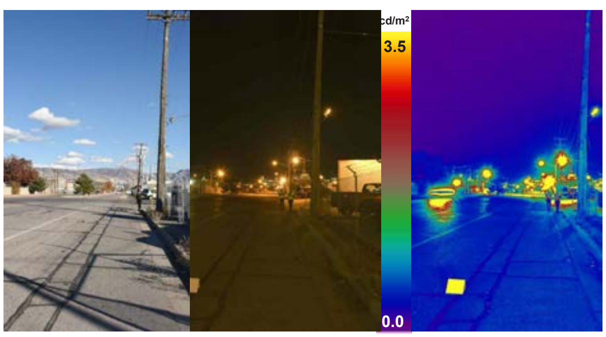
Site 3 : Redwood Rd & S Temple

Collector / Industrial

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

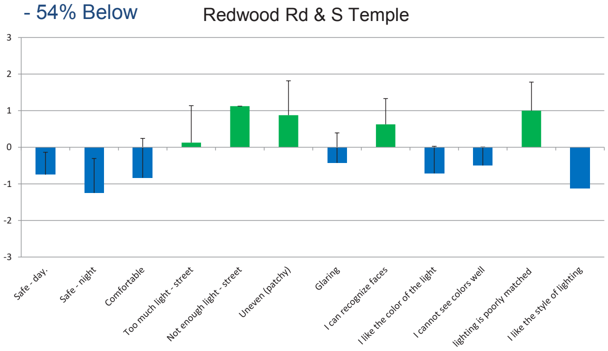
February 2019



Level of Acceptability: Poor (Lighting Score = -2.9)
S. Temple is lit with HPS luminaires in a staggered arrangement and does not meet roadway criteria.

% From Criteria:
- 54% Below

Green Bars are Positive Responses
Blue Bars are Negative Responses



Initial Site Observations
- This site is an industrial part of town next to a ABF Freight.
- There is no sidewalk on either side of the road and very minimal pedestrian traffic.
- S. Temple dead ends at private property to the east.

Lighting Measurements
- The street is under lighted and does not meet roadway criteria.
- The are currently no sidewalks, and light does not meet the edge of roadway where pedestrians would be walking.

Participant Survey
- Participants were very uncomfortable with this site.
- Participants did not feel safe on this site during the day *or* night, due to the industrial location.
- Participants felt that there was not enough light at this site.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Low Conflict	Average	0.3	0.08	0.4
	Ave/Min	6	-	4
Site 3	Average	0.1	0.0	0.2
	Ave/Min	1.3	-	2.3

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LIGHTING DESIGN AND ENGINEERING

Site 3 : Redwood Rd & S Temple

Collector / Industrial

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

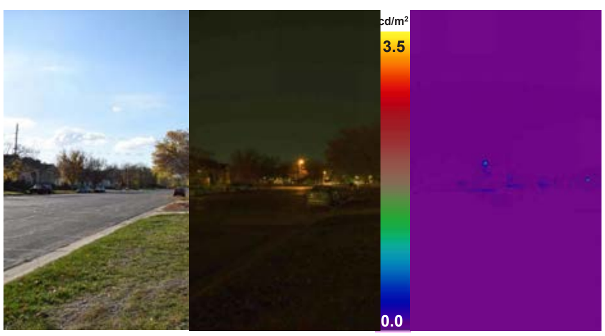
February 2019

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 4: 700S Post Street
Local / Residential

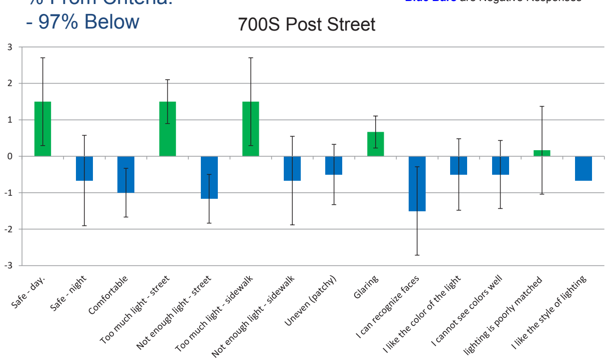
Salt Lake City – Existing Street Lighting Conditions

February 2019



% From Criteria:
- 97% Below

Green Bars are Positive Responses
Blue Bars are Negative Responses



Level of Acceptability: Poor (Lighting Score = -1.8)
700S is an extremely wide residential street with cobrahead style luminaires at intersections.

Initial Site Observations
- 700S is an extremely wide residential street and was described by one resident as an "air strip."
- The streets in this area are lit by HPS luminaires located at intersections. Current luminaires are not capable of providing light across the wide intersections.

Lighting Measurements
- This street is dark and only lit by passing cars.
- There is no light on sidewalks except directly below luminaires.

Participant Survey
- Participants felt uncomfortable in this location at night, but very safe during the day, which indicates additional lighting could be helpful.
- They felt strongly that there was not enough light on the roadway or sidewalk and were not able to identify faces and colors.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Local Criteria Low Conflict	Average	0.3	0.08	0.3
	Ave/Min	6	-	6
Site 4	Average	0.0	0.0	0.0
	Ave/Min	-	-	-

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 4: 700S Post Street
Local / Residential

Salt Lake City – Existing Street Lighting Conditions

February 2019

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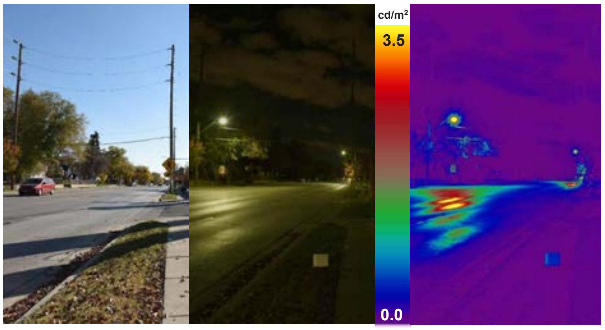
CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 5 : 900W & Dalton Ave
Arterial / Residential

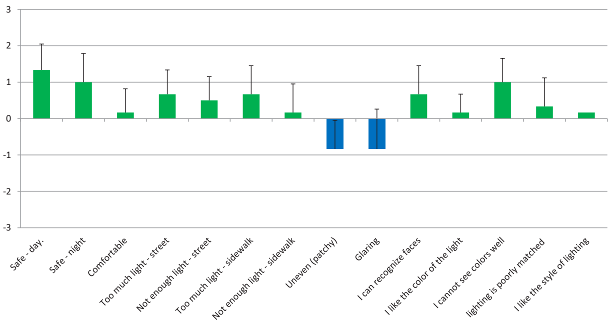
Public Utilities

Salt Lake City – Existing Street Lighting Conditions
February 2019



Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
137% Above



Level of Acceptability: Acceptable (Lighting Score = 5.2)
900W is an arterial street lit by HPS luminaires in a staggered arrangement.

Initial Site Observations
- This is a 5 lane arterial road next to Jordan Park.
- Luminaires are LED and are in a staggered arrangement.
- Sidewalks are separated from roadway by landscaping, but have sufficient horizontal illuminance.

Lighting Measurements
- Heavy traffic while measurements were being taken contributed to light levels.
- Roadway luminance measurements meet criteria, but street feels slightly underlit.
- Sidewalk horizontal criteria is met, but vertical illuminance is low.

Participant Survey
- Participants felt that the lighting was patchy and that trees obstructed light from hitting the sidewalks.
- Overall they felt that this wide street had good coverage, however light sources appeared glaring.
- Participants were split over if the sidewalks were sufficiently lit or not.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Arterial Criteria Low Conflict	Average	0.3	0.08	0.6
	Ave/Min	6	-	3.5
Site 5	Average	0.3	0.0	1.4
	Ave/Min	2.9	-	5.1

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 5 : 900W & Dalton Ave
Arterial / Residential

Public Utilities

Salt Lake City – Existing Street Lighting Conditions
February 2019

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

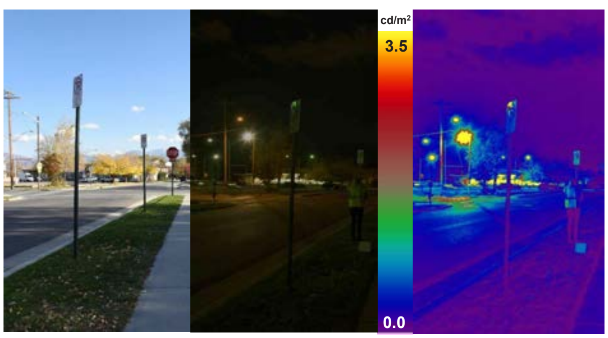
Site 6 : Glendale Dr. & Navajo St

Collector / Residential / Commercial

Public Utilities

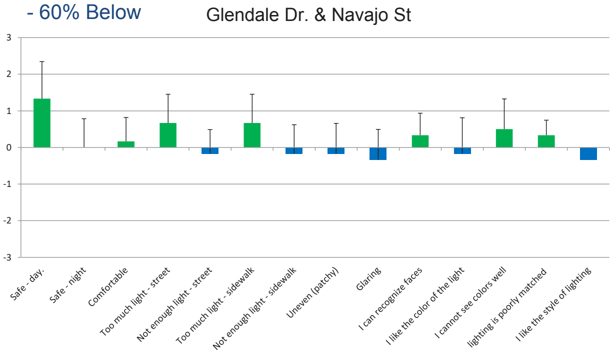
Salt Lake City – Existing Street Lighting Conditions

February 2019



Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
- 60% Below



Level of Acceptability: Moderate (Lighting Score = 2.7)
Glendale Dr. is lit by HPS lights and also sees major contribution from nearby private lighting.

Initial Site Observations

- This is a residential/commercial area near the US Dream Academy and a Church.
- The street lighting is located midblock and at intersections, but private lighting from parking lots contribute to light on the street and sidewalk.
- Building mounted lights are glaring and shine into residences across the street.

Lighting Measurements

- The roadway is under lighted, even with contribution from private lighting.
- The horizontal and vertical illuminance on the sidewalk does not meet criteria.

Participant Survey

- Participants felt that the lighting was patchy with different types and colors and several dark areas.
- Overall they were split over the nighttime conditions.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Medium Conflict	Average	0.5	0.2	0.6
	Ave/Min	4	-	3.5
Site 6	Average	0.2	0.0	0.2
	Ave/Min	1.5	-	1.7

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 6 : Glendale Dr. & Navajo St

Collector / Residential / Commercial

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

February 2019

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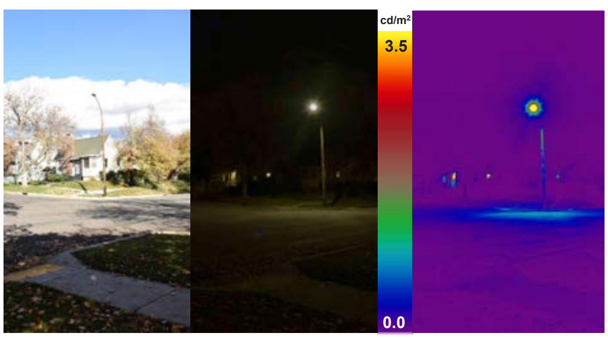
CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 7 : Jay St & 1st Ave
Local / Residential

Public Utilities

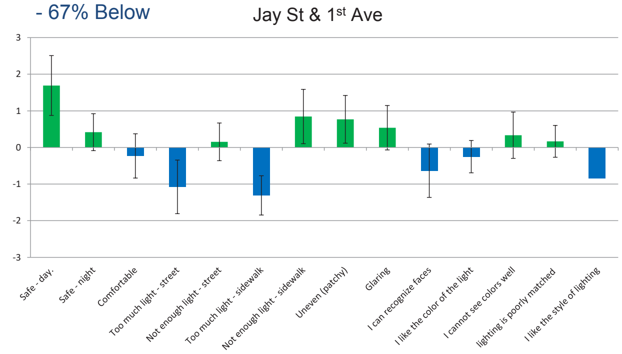
Salt Lake City – Existing Street Lighting Conditions
February 2019



Level of Acceptability: Poor (Lighting Score = -0.3)
2nd Ave is residential street lit by a single HPS luminaire at each intersection.

Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
- 67% Below



Initial Site Observations
- This site is located in a residential neighborhood adjacent to a Church.
- Sidewalks are separated from the road by landscaping and feel dark. Large trees shadow the sidewalks.
- Sidewalk adjacent to the Church has light contribution from parking lot lighting.

Lighting Measurements
- The luminance on 2nd Ave does not meet criteria for a local street, but the lighting layout is in accordance with the current SLC Street Lighting Masterplan.
- Sidewalks are dark and do not have any light, except directly below luminaire.

Participant Survey
- Participants felt that the street light only sufficiently illuminates the intersection. The remaining roadway and the sidewalks are dark.
- Participants were split on nighttime safety and comfort levels.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Local Criteria Low Conflict	Average	0.3	0.08	0.3
	Ave/Min	6	-	6
Site 7	Average	0.1	0.0	0.1
	Ave/Min	9.9	-	3.3

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 7 : Jay St & 1st Ave
Local / Residential

Public Utilities

Salt Lake City – Existing Street Lighting Conditions
February 2019

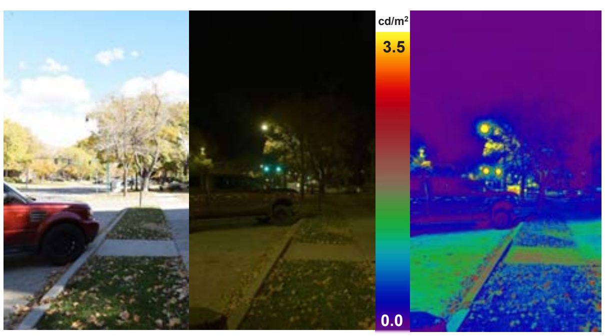
CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

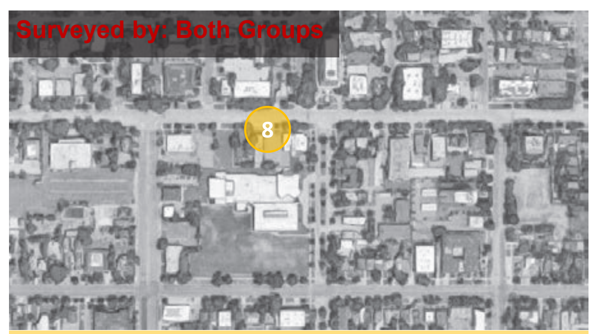
Site 8 : 800E & S. Temple
Arterial / Commercial

Salt Lake City – Existing Street Lighting Conditions

Public Utilities

February 2019

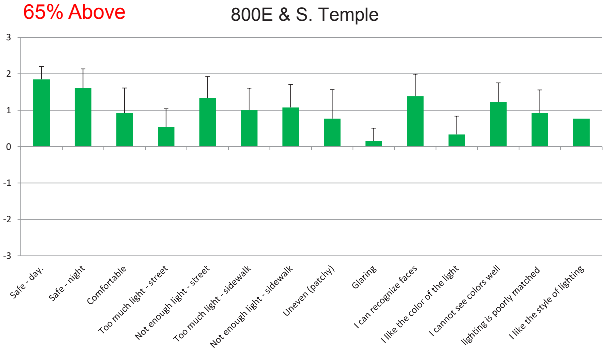




% From Criteria:
65% Above

Green Bars are Positive Responses
Blue Bars are Negative Responses

800E & S. Temple



Level of Acceptability: Excellent (Lighting Score = 13.9)
S. Temple is lit using LED Acorn style luminaires arranged in an opposite arrangement.

Initial Site Observations
- S. Temple is a 4 lane arterial road connecting downtown, the avenues and the University.
- This is a commercial area with a restaurants, condominiums and businesses nearby.
- Sidewalks are separated from the street by landscaping and are shadowed by large trees. Additional pedestrian lights are placed at crosswalks.

Lighting Measurements
- Heavy traffic while measurements were being taken contributed to light levels.
- Roadway luminance far exceeds criteria, but light levels felt appropriate for this street.
- Sidewalks are slightly below criteria, and there is some light contribution from nearby businesses.

Participant Survey
- Participants felt that the lighting at this sight was better than other similar site throughout the city.
- Participants were split on light levels. Some felt it was too bright, while others desired slightly more light.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Arterial Criteria Medium Conflict	Average	0.5	0.2	0.9
	Ave/Min	4	-	3
Site 8	Average	0.4	0.1	1.5
	Ave/Min	3.0	-	1.8

Site 8 : 800E & S. Temple
Arterial / Commercial

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Salt Lake City – Existing Street Lighting Conditions

Public Utilities

February 2019

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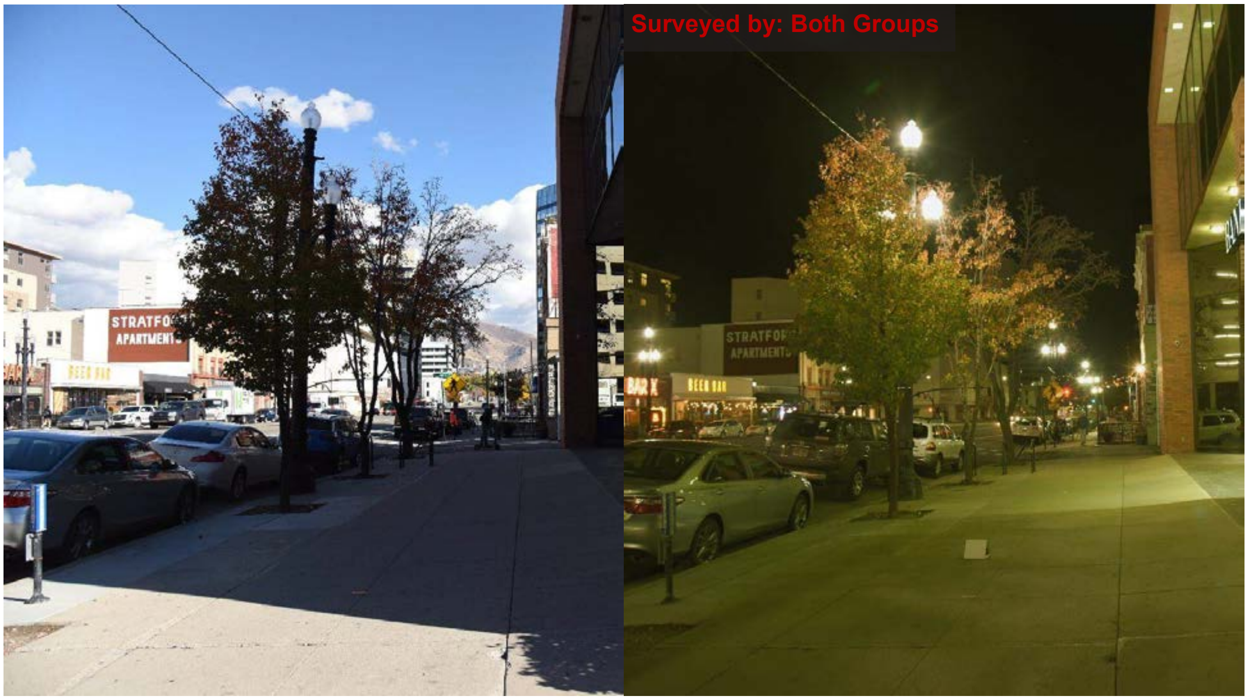


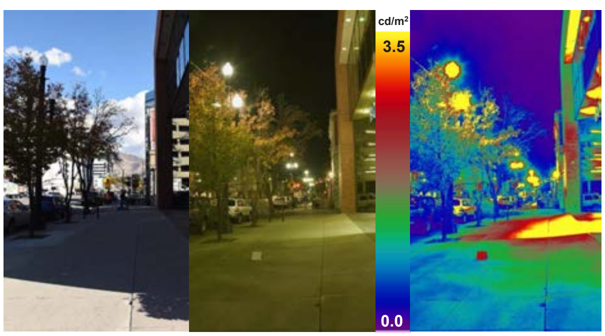
Site 9 : 200S Floral St
Arterial / Commercial

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

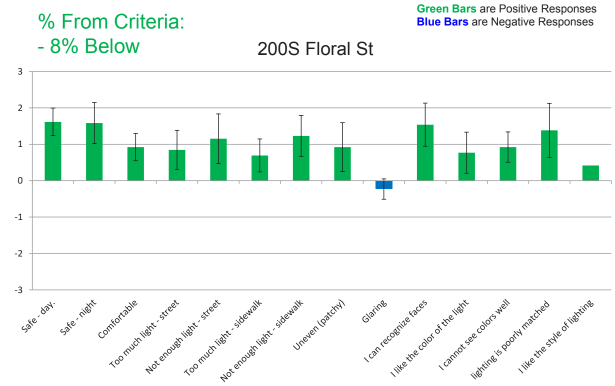
February 2019



Level of Acceptability: Excellent (Lighting Score = 13.8)
200S is an arterial road running through the heart of downtown with cactus style poles.

% From Criteria:
- 8% Below

Green Bars are Positive Responses
Blue Bars are Negative Responses



Initial Site Observations
- This site is in the heart of downtown SLC nearby multiple bars and restaurants.
- Cactus style poles are closely spaced on both sides of the road.
- There is a large, non signalized, mid block crosswalk across 200S.

Lighting Measurements
- The roadway essentially meets criteria at this site and feels comfortable.
- The cactus poles use acorn style luminaires that provide good vertical illuminance on pedestrians.
- This site is essentially meets all criteria.

Participant Survey
- Participants felt that the lighting at this site was better then similar areas throughout the city.
- Participants felt that the light sources were glaring and light could be better directed toward the street.
- Participants also felt that the light fixtures meet the character of the area, but there are too many of them.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Arterial Criteria Medium Conflict	Average	0.5	0.2	0.9
	Ave/Min	4	-	3
Site 9	Average	0.8	0.5	0.8
	Ave/Min	4.2	-	1.7

Site 9 : 200S Floral St
Arterial / Commercial

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LIGHTING DESIGN AND ENGINEERING

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

February 2019

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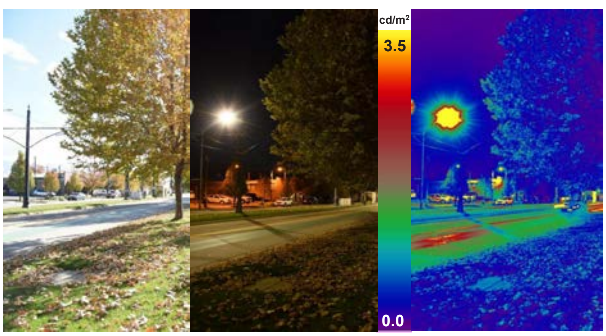
LIGHTING DESIGN AND ENGINEERING

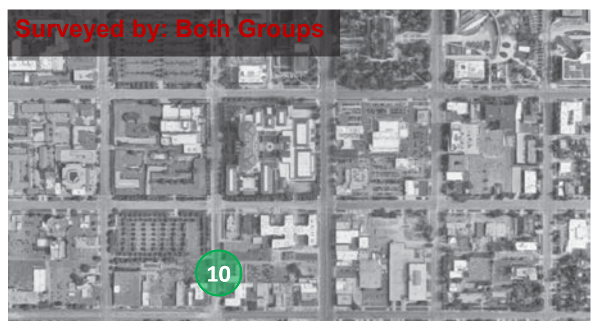
Site 10 : 650S Main Street
Arterial / Commercial

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

February 2019

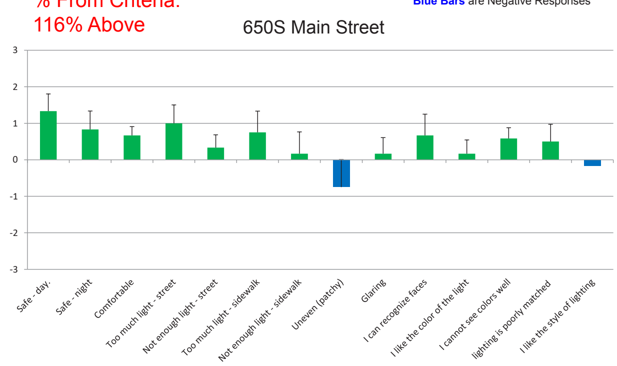




Level of Acceptability: Acceptable (Lighting Score = 6.3)
Main St. is a collector street with a shared transit line, lit with LED luminaires in a staggered arrangement.

% From Criteria:
116% Above

Green Bars are Positive Responses
Blue Bars are Negative Responses



Initial Site Observations
- Main St. is shared by both vehicles and the TRAX line.
- North and Southbound lanes are separated by a large landscape median that supplies power for TRAX.
- Sidewalks are separated from the road by landscaping and are shaded by large trees.

Lighting Measurements
- The roadway exceeds criteria. Luminaires used are glaring.
- Sidewalk essentially meets criteria, but have significant contribution from private lighting.
- Overall, this site is well lit.

Participant Survey
- Participants felt that the trees blocked a lot of light to the sidewalks which caused the light to be uneven.
- Overall, participants felt that the roadway was sufficiently lighted.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Medium Conflict	Average	0.5	0.2	0.6
	Ave/Min	4	-	3.5
Site 10	Average	0.4	0.1	1.3
	Ave/Min	2.5	-	1.6

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LIGHTING DESIGN AND ENGINEERING

Site 10 : 650S Main Street
Arterial / Commercial

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

February 2019

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LIGHTING DESIGN AND ENGINEERING

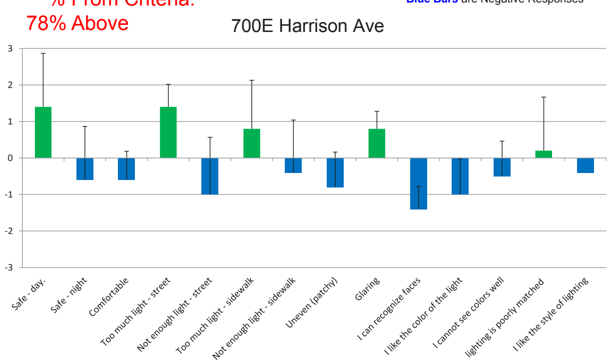
Site 11 : 700E Harrison Ave
Arterial / Residential

Salt Lake City – Existing Street Lighting Conditions
February 2019

Level of Acceptability: Poor (Lighting Score = -2.1)**
700E is a large arterial road spanning the whole Salt Lake valley with heavy traffic.

** % From Criteria:
78% Above

Green Bars are Positive Responses
Blue Bars are Negative Responses



Initial Site Observations
- 700E is a 7 lane arterial road with heavy commuter and shipping traffic, along with bike lanes that runs throughout the whole valley.
- The site is adjacent to Herman Franks Park and Liberty Park.
- The roadway is lit using LED luminaires in a staggered arrangement.

Lighting Measurements
- The roadway exceeds lighting criteria, but luminance levels feel appropriate for this size of street.
- Light on the sidewalk does not meet horizontal or vertical illuminance criteria, but heavy traffic provides additional light.

Participant Survey
- ****Lights on the west side of the roadway were not operational during surveys.****
- Overall, participants felt this site was dark and was worse than similar sites throughout the city.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Arterial Criteria Medium Conflict	Average	0.5	0.2	0.9
	Ave/Min	4	-	3
Site 11	Average	0.2	0.0	1.6
	Ave/Min	1.7	-	4.6

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 11 : 700E Harrison Ave
Arterial / Residential

Salt Lake City – Existing Street Lighting Conditions
February 2019

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Site 12 : 9th & 9th

Arterial / Commercial

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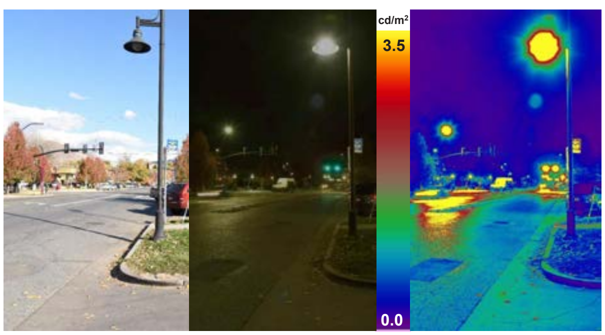
LIGHTING DESIGN AND ENGINEERING

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

February 2019



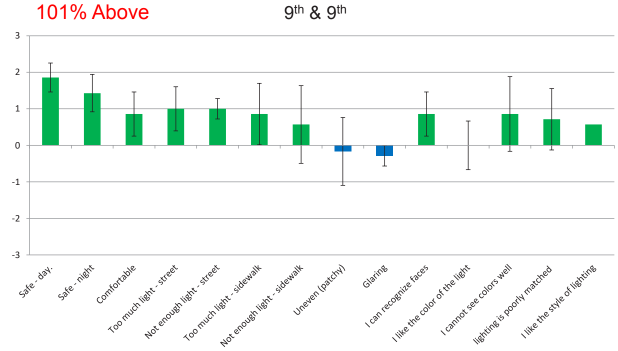
Level of Acceptability: Acceptable (Lighting Score = 10.1)

900S is a collector street in a commercial area with by pedestrian style luminaires

% From Criteria:
101% Above

9th & 9th

Green Bars are Positive Responses
Blue Bars are Negative Responses



Initial Site Observations

- 9th & 9th is a bustling commercial area and a destination in Salt Lake.
- The streets and sidewalks are lit mostly by pedestrian style luminaires along with cobra heads mounted on signal poles.
- Landscaping and on street parking separate the sidewalk from the roadway.

Lighting Measurements

- Overall, this site meets or exceeds the lighting criteria.
- The roadway luminance exceeds the target criteria, but luminance levels feel appropriate on the street.
- Sidewalk horizontal and vertical illuminance criteria is met.

Participant Survey

- Participants felt that this site was appropriately lit and was better than similar sites throughout the city.
- Participants noted that lighting could be better controlled and less glaring.
- Participants liked the style of lighting for the neighborhood character.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Medium Conflict	Average	0.5	0.2	0.6
	Ave/Min	4	-	3.5
Site 12	Average	0.5	0.3	1.2
	Ave/Min	5.6	-	2.0

Site 12 : 9th & 9th

Arterial / Commercial

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LIGHTING DESIGN AND ENGINEERING

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

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LIGHTING DESIGN AND ENGINEERING

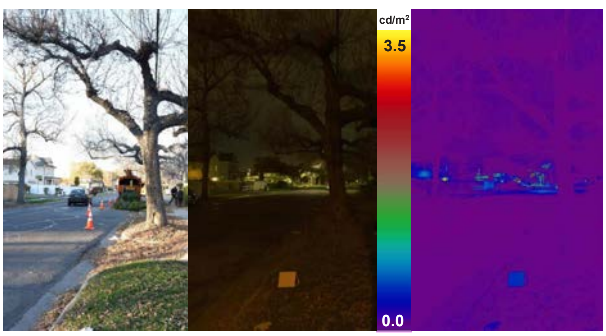
Site 13 : Layton Ave & W Temple

Local / Residential

Salt Lake City – Existing Street Lighting Conditions

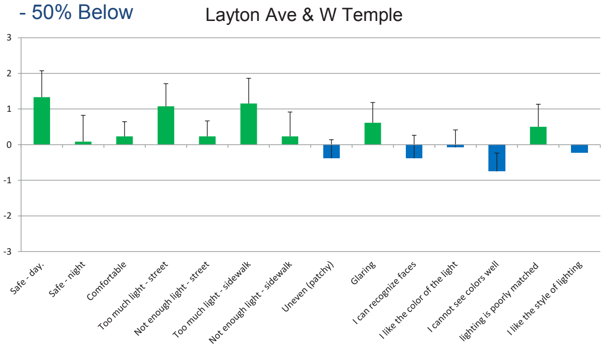
Public Utilities

February 2019



% From Criteria:
- 50% Below

Green Bars are Positive Responses
Blue Bars are Negative Responses



Level of Acceptability: Moderate (Lighting Score = 3.6)
West Temple is a collector road passing through residential area lit with HPS Luminaires along one side of the road.

Initial Site Observations

- West Temple is a 2 lane collector road passing through a residential area lit with HPS lights along the east side of the road.
- Large, dense trees block most of the light from hitting the roadway or sidewalk.

Lighting Measurements

- Due to the large trees, most of the light does not reach to ground, causing the roadway and sidewalks to be under lighted.
- Sidewalks feel dark is dramatic shadowing from trees.

Participant Survey

- Participants were split on how appropriate the roadway and sidewalk lighting was.
- Participants were also split on nighttime safety and comfort levels at this site.
- Overall, this is a very polarizing site.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Low Conflict	Average	0.3	0.08	0.4
	Ave/Min	6	-	4
Site 13	Average	0.1	0.0	0.2
	Ave/Min	6.5	-	10.1

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 13 : Layton Ave & W Temple

Local / Residential

Salt Lake City – Existing Street Lighting Conditions

Public Utilities

February 2019

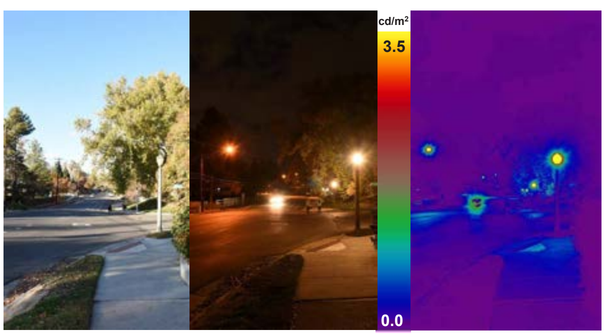
CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 14 : 1500S Yale Ave
Collector / Residential

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

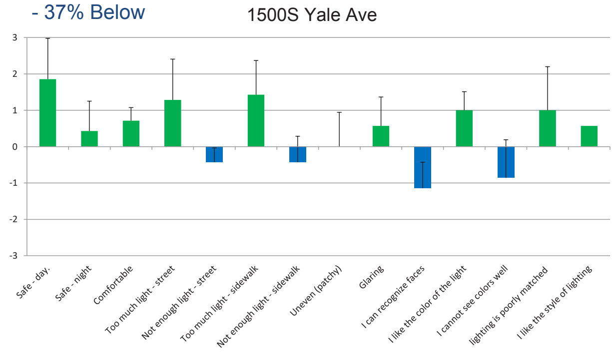
February 2019



% From Criteria:
- 37% Below

Green Bars are Positive Responses
Blue Bars are Negative Responses

1500S Yale Ave



Level of Acceptability: Acceptable (Lighting Score = 6.0)
1500S is a collector road bordering neighborhoods with Enhanced and base level lighting.

Initial Site Observations
- This site has both cobrahead HPS lights as well as acorn style lights that are part of the Enhanced Lighting Program.
- 1500S is a collector street connecting multiple residential areas with private and enhanced street lighting.

Lighting Measurements
- The street is slightly below criteria, but feels appropriate in this area.
- Sidewalk lighting does not meet horizontal or vertical criteria.
- Overall the site does not meet criteria, but feels lighting feels appropriate to the area.

Participant Survey
- Participants were divided on if the lighting was better or worse compared to similar areas, however they did generally agree that this street might need additional lighting.
- Overall, participants felt that this site could use additional light.
- ★ Survey was taken in a different location than the measurements were.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Low Conflict	Average	0.3	0.08	0.4
	Ave/Min	6	-	4
Site 14	Average	0.2	0.0	0.3
	Ave/Min	5.5	-	8.4

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 14 : 1500S Yale Ave
Collector / Residential

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

February 2019

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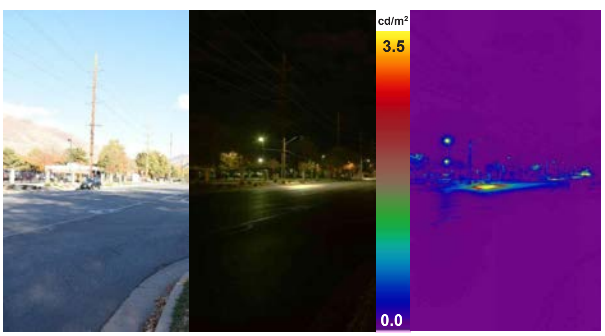
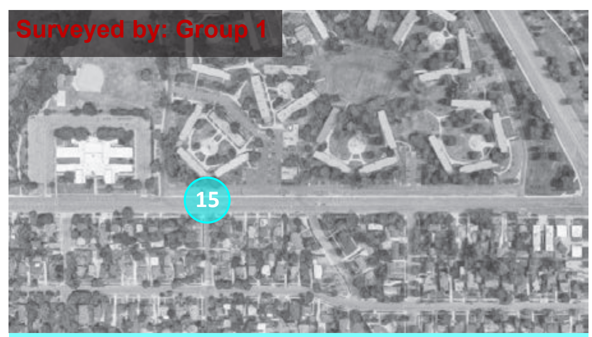
Site 15 : 19th E & Sunnyside Ave

Arterial / Residential / Commercial

Salt Lake City – Existing Street Lighting Conditions

February 2019

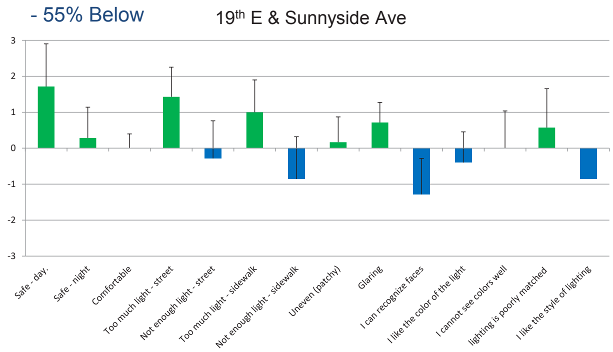




Level of Acceptability: Moderate (Lighting Score = 2.2)
Sunnyside Ave is an arterial street connecting the residential neighborhoods with the University and Foothills.

Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
- 55% Below



Initial Site Observations

- This 5 lane arterial street is lit with LED lights from the north side of the road at a large spacing.
- The side borders residential neighborhoods, Sunnyside Park, a church, University housing and is a major path into the University of Utah campus and to downtown.
- Lights are glaring and cause light trespass at residences across the street.

Lighting Measurements

- Both the sidewalk and roadway are under lighted and do not meet criteria.
- Lights are spaced too far apart and overly bright and glaring luminaires are used to help get light across and down the street.

Participant Survey

- Participants felt that the lighting was insufficient on the south side of the road, due to the single-side lighting arrangement.
- Overall, participants felt that this lighting was worse than similar areas and could use additional light.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Arterial Criteria Medium Conflict	Average	0.5	0.2	0.9
	Ave/Min	4	-	3
Site 15	Average	0.1	0.0	0.4
	Ave/Min	5.7	-	2.3

Site 15 : 19th E & Sunnyside Ave

Arterial / Residential / Commercial

Salt Lake City – Existing Street Lighting Conditions

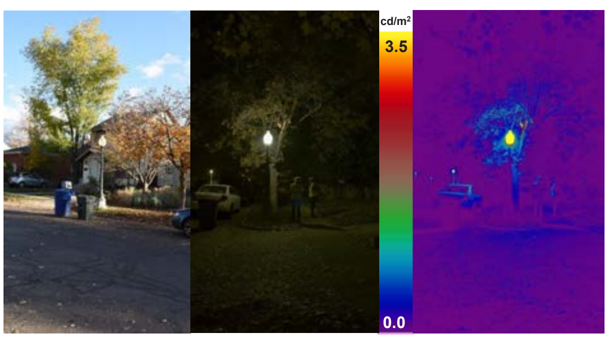
February 2019

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 16 : 1400E Redondo Ave
Local / Residential

Public Utilities

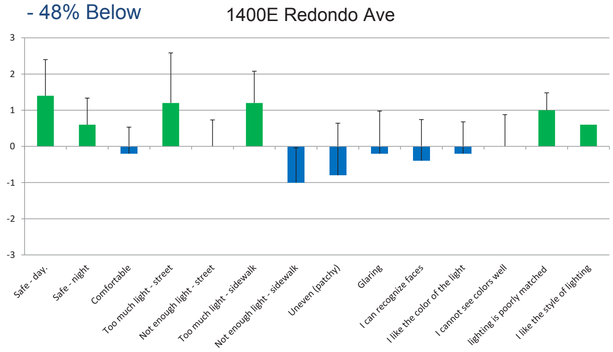
Salt Lake City – Existing Street Lighting Conditions
February 2019



Green Bars are Positive Responses
Blue Bars are Negative Responses

% From Criteria:
- 48% Below

1400E Redondo Ave



Level of Acceptability: Moderate (Lighting Score = 3.2)
Redondo Ave is a residential street in the Sugarhouse area with private street lighting.

Initial Site Observations
- Redondo Ave is a residential street with private acorn style street lights.
- Multiple lights along the street were burnt out or malfunctioning.
- Large trees on the street shaded most of the lights.

Lighting Measurements
- This site does not meet roadway or sidewalk criteria.
- The infrastructure for decent street lighting is present, but multiple lights were not on resulting in a dark street.

Participant Survey
- Some participants felt that the light sources were glary, and provided patchy, insufficient light coverage.
- Participants liked the style of lights, but they did not feel comfortable, and would like to see more light on the roadway and sidewalk.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Local Criteria Low Conflict	Average	0.3	0.08	0.3
	Ave/Min	6	-	6
Site 16	Average	0.1	0.0	0.0
	Ave/Min	5.3	-	-

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

Site 16 : 1400E Redondo Ave
Local / Residential

Public Utilities

Salt Lake City – Existing Street Lighting Conditions
February 2019

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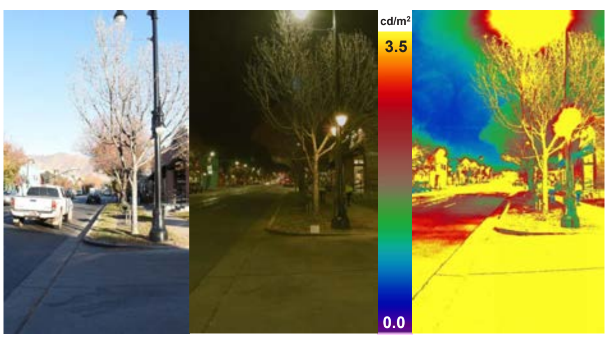
LIGHTING DESIGN AND ENGINEERING

Site 17: 1000E 2100S
Local / Commercial

Public Utilities

Salt Lake City – Existing Street Lighting Conditions

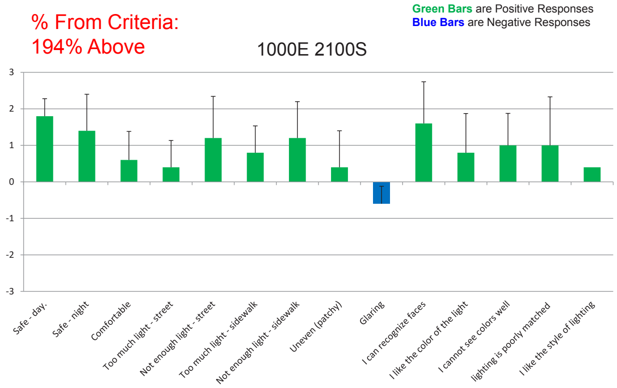
February 2019



Level of Acceptability: Acceptable (Lighting Score = 12.0)
2100S is in the heart of the Sugarhouse business district and is part of the Special Assessment Lighting program

% From Criteria:
194% Above

Green Bars are Positive Responses
Blue Bars are Negative Responses



Initial Site Observations
- The site is in the middle of the Sugarhouse business district and is surrounded by commercial properties.
- The luminaires used at this site have a street light as well as two pedestrian level light sources.
- 2100S is a four lane arterial road and luminaires are in an opposite arrangement.
- Acorn style luminaires are bright and slightly glaring.

Lighting Measurements
- There is a lot of light at this site and all criteria is exceeded.
- Multi-head luminaires with street and pedestrian luminaires plenty of light on the sidewalk and street.

Participant Survey
- Most participants felt that there was too much light, and that the light sources were glaring.
- Overall, participants felt safe at this location.

		Sidewalk Illuminance (fc)		Roadway Luminance (cd/m^2)
		Horizontal	Vertical (min)	
Collector Criteria Medium Conflict	Average	0.5	0.2	0.6
	Ave/Min	4	-	3.5
Site 17	Average	2.5	0.3	1.8
	Ave/Min	8.2	-	2.6

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LIGHTING DESIGN AND ENGINEERING

Site 17: 1000E 2100S
Local / Commercial

Public Utilities

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February 2019

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Salt Lake City Street Lighting Master Plan

Nocturnal Infrastructure for Ecological Health

Prepared by: Travis Longcore, Ph.D.
Prepared for: Clanton and Associates, Boulder, Colorado

May 2020

Lights of Salt Lake City wash out the Milky Way viewed from Antelope Island State Park. Photograph: Ryan Andreasen.

Table of Contents

1 Introduction

Salt Lake City is located in a region connected to its night sky. The awe and wonder inspired by a view of the Milky Way and sky overflowing with stars attracts visitors to Utah and contributes to the identity of the region for residents. Salt Lake City itself is brightly illuminated, with its cultural and institutional centers, commercial zones, and unique urban design. But just north of the city, Antelope Island State Park has sought and received recognition as a Dark Sky Park by the International Dark-Sky Association, joining eight other Dark Sky Parks, a Dark Sky Community, and a Dark Sky Heritage Place in Utah (Figure 1). The future of Antelope Island's long-term status as a Dark Sky Park depends on the decisions of the cities along the Wasatch Front in protecting the night sky (see cover).

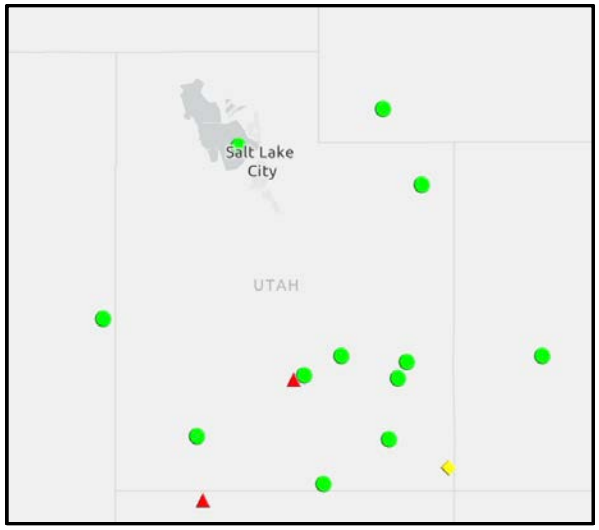


Figure 1. Distribution of recognized dark sky places in and near Utah. Circles are Dark Sky Parks, triangles are Dark Sky Communities, and diamonds are Dark Sky Heritage Sites. Source: List of Dark Sky Places maintained by Dark Skies Advisory Group, IUCN.

Cities set the tone for night lighting in a region. They are the most brightly lit, and their size influences the markets, practices, and professionals in a region. Commercial zones of cities and towns tend to contribute the most light escaping upward (and therefore wasted), along with lighted sports fields when they are illuminated (Luginbuhl et al. 2009). Historically, street lights contributed a significant and constant amount to both useful and wasted light through the night, while residential lights and lighting from vehicles declines substantially through course of the night (Bará et al. 2017). Within residential zones, most of the light is from the streetlighting system, especially later in the evening when traffic rates are low and ornamental lighting is switched off (Bará et al. 2017). Decisions made at municipal level about its street lighting system therefore have a large contribution to the overall amount of useful and wasted light in a city. Because perception of lighting is based on contrasts (the same light appears dim next to a brighter source and bright next to a dimmer source), the decisions made in terms of municipal street lighting systems have ramifications to the nocturnal environment that extend beyond the system itself. As a metropolitan area, compared with the 125 largest metropolitan areas in the United States, Salt Lake City is well above average in terms of the average amount of light escaping upward that can be measured by satellites (Figure 2). It does not waste as much light as other larger cities with their greater areas, but on a per area basis it contributes more to regional light pollution than the average city, although not so much as New Orleans, which is a similar size.

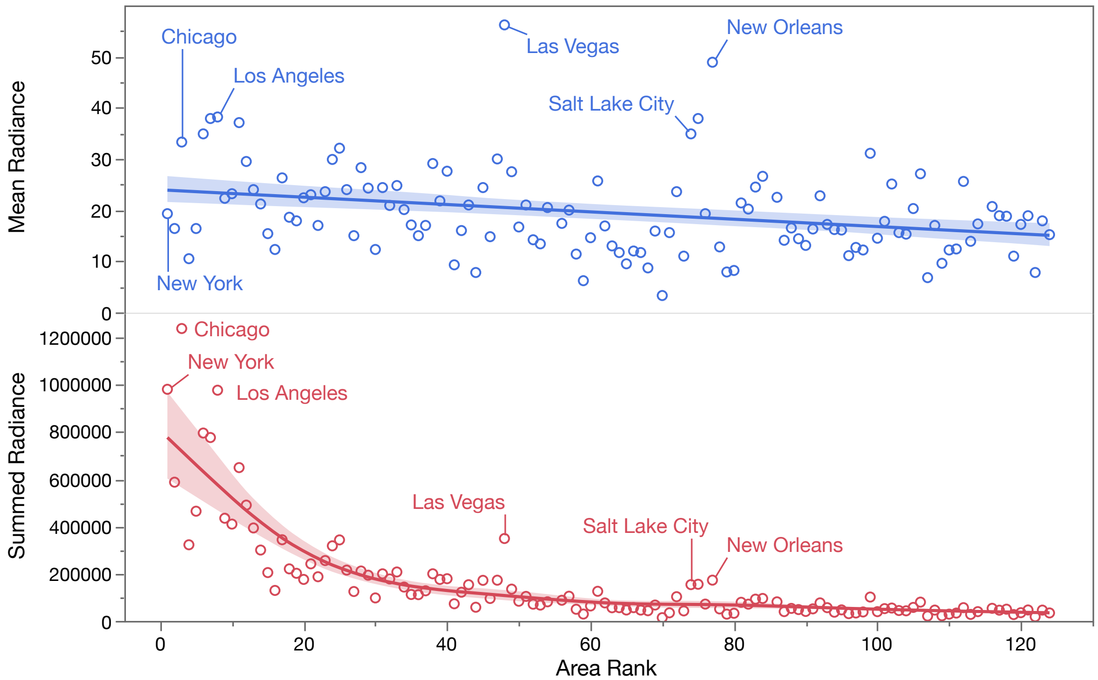


Figure 2. Light escaping upwards from Salt Lake City 2012–2017 within the 125 largest metropolitan regions in the United States. Top: radiance normalized for area. Bottom: total radiance from entire city extent. Data from VIIRS DNB as analyzed by Horton et al. (2019).

Large-scale transformations of municipal street lighting systems have occurred over the past decade as older lighting technologies have been replaced by light emitting diode (LED) systems. Because of the history of the technology, where the early high-efficiency LEDs had a high content of blue light, residents of many jurisdictions objected to the new lights. The bluish-white light of LEDs in those installations was perceived as brighter because of the visual sensitivity of the human eye to the greater proportion of shorter (blue) wavelengths in the light produced. In addition, when lights are more efficient and less expensive to operate, there is a tendency to use more light (Kyba et al. 2014). Not only does the color of light affect how humans perceive the lights; the color of lights is recognized as influencing the contributions lights have to light pollution (Aubé et al. 2013, Kinzey et al. 2017), wildlife (Longcore et al. 2015b, Donners et al. 2018, Longcore 2018), and human health (Garcia-Saenz et al. 2018).

Researchers and engaged lighting designers are developing techniques to minimize undesirable effects of outdoor lighting on both astronomical and ecological light pollution. These include guidance for protected lands (Longcore and Rich 2017), recommendations for specific groups of species (Voigt et al. 2018), and recommendations balancing human vision and wildlife impacts (Longcore et al. 2018a). As Salt Lake City prepares a new Street Lighting Master Plan, this research can be synthesized and applied to inform decisions about the design of the future street lighting system that is consistent with the values embodied in the plan.

This report provides guidance for minimizing the adverse impacts of unnecessary light at night on species, habitats, and ecosystems in the development of a Street Lighting Master Plan for Salt Lake City. The organization of the report is as follows. In the next chapter, the potential impacts of street lighting on wildlife in Salt Lake City are reviewed, based on the published scientific research. The following chapter explores the role of spectrum in determining the level of impact on dark skies, circadian rhythms, and wildlife. Then, this information is synthesized in a chapter outlining spatially explicit design strategies to reduce adverse impacts of street lighting on sensitive biological resources within the context of the further development of Salt Lake City's municipal lighting system. With these strategies, Salt Lake City can build a nocturnal infrastructure that supports ecological health by providing high-quality lighting for human safety and well-being while protecting the night sky and nighttime environment within the city and across the region, setting an example for others to follow.

2 Potential Impacts of Streetlights on Wildlife in Salt Lake City

Street lighting has a large spatial footprint within the area of a city. For a medium-sized city like Salt Lake City, street lighting is provided throughout its residential, commercial, and industrial districts to different extents. In this chapter, the potential effects of this system on wildlife are considered, which requires assessment of the geographic extent of the city.

To describe the environment potentially affected by lighting in Salt Lake City, the physical geography and habitats of the city were described and lists of sensitive species were compiled. Together, these natural features and species distributions can provide the background to devise spatially explicit schemes to minimize potentially adverse effects.

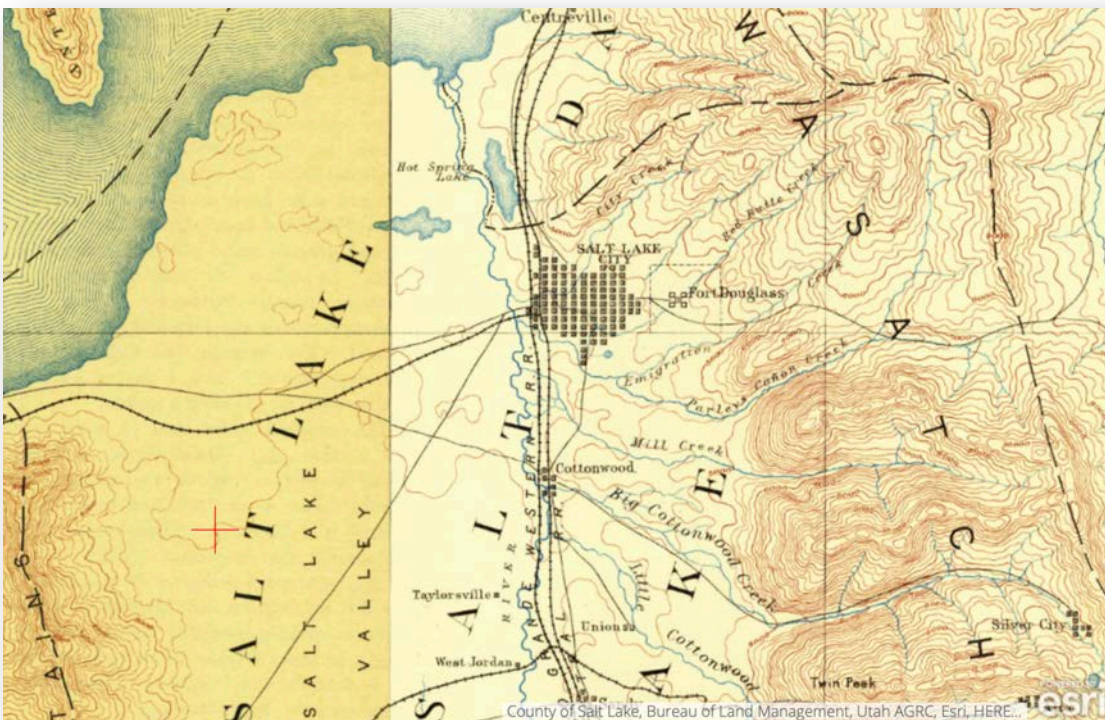


Figure 3. Location of Salt Lake City within the physical geography of the region (USGS topographic maps, 1885, from http://historicalmaps.arcgis.com/usgs/).

2.1 Physical Geography

Salt Lake City is located on lacustrine terraces between the Wasatch Mountains and the Great Salt Lake. It grew up as a central location for travel, commerce, and mining, supported by a swath of irrigated lands extending north-south along the Wasatch Mountains. Although other regional cities were established first (e.g., Ogden), Salt Lake City arose as the most significant city through a confluence of its irrigation resources and its importance as a religious center.

The growth of Salt Lake City depended in part on the array of some 35 streams that flowed downward from the Wasatch Mountains to the rich soils of the terraces above the Great Salt Lake (Harris 1941). These streams were not deeply incised and therefore they could be diverted for irrigation, compared with the rivers of the region, which although larger, are incised into canyons and consequently could not be used easily be irrigation by the white settlers in the 1840s. The climate is mild, with a long growing season extended by proximity to the Great Salt Lake. Snow accumulation in the mountains and a long melt season made agriculture attractive and productive within the region. The creeks flowing out of the Wasatch Mountains, City Creek, Red Butte Creek, Emigration Creek, Parley's Cañon Creek (now Parley's Creek), Big Cottonwood Creek, in turn flowed into the Jordan River, which flowed northward to debouche through a small distributary delta into the Great Salt Lake (Figure 3). The Jordan River has a winding, low-gradient pathway that remains to this day, dividing the territory of the city into eastern and western halves. The eastern half is characterized by the rising terraces climbing up toward the mountains with the remaining extents of the westward-flowing creeks, while the western portion of the city is an almost entirely flat open plain extending toward the shore of the Great Salt Lake (Figure 3).

These features of the physical geography of Salt Lake City are a useful organizing framework to discuss zones that remain important to the ecology and sensitive species of the City today: 1) the Salt Lake shorelands, 2) the Jordan River, 3) the urban creeks, and 4) the Wasatch Mountains.

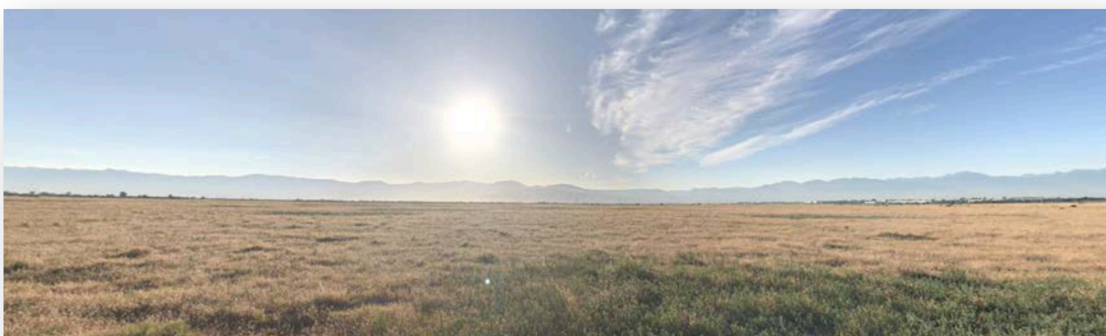


Figure 4. Example of the open landscape of the Great Salt Lake shorelands. Photo from Google Local Guide Neil Martin, looking due east toward Salt Lake City.

2.1.1 Great Salt Lake Shorelands

The shorelands surrounding the Great Salt Lake extend far into the City limits of Salt Lake City. The airport and western commercial and industrial areas extend into this zone. These flat, open areas are made up of deep lacustrine sediments of clay and loam (Flowers 1934). Although the vegetation changes by zones extending away from the lake, the plains and ponds within them tend to be saline, which leads to a flora free from trees and dominated by low succulent herbs and low shrubs, such as pickleweed, salt bush, salt grass, and seepweed (Flowers 1934). Open habitats such as these (Figure 4) are vulnerable to disruption by light pollution because light encounters no barriers and even a single unshielded streetlight can be seen from a great distance

(De Molenaar et al. 2006, Longcore and Rich 2017). Birds in landscapes like this can be influenced by the direct glare from streetlights and will locate nests farther from lights when such sites are available (De Molenaar et al. 2006).

These shoreland ecosystems are extremely important to shorebirds for foraging and breeding. The brine shrimp and salt flies that feed on algae in and around the lake provide food and the undisturbed open areas are used by Snowy Plovers, American Avocets, Black-necked Stilts, Long-billed Curlew, and dozens of other shorebird and waterbird species (Jones 2008). A portion of this area with Salt Lake City has been established and managed as the Inland Sea Shorebird Reserve by Rio Tinto/Kennecott as mitigation for impacts from its nearby mining operations. They took advantage of existing shallow depressions with soils high in clay that naturally held water and managed the drainage system to extend inundation times and provide high-quality bird habitat. The 3,670-acre reserve provides habitat for around 120,000 birds annually.

The Great Salt Lake as a whole has been recognized as a site of "hemispheric importance" within the Western Hemisphere Shorebird Network (Andres et al. 20016). Nearly all the western shorelands with Salt Lake City have been designated as Very Important Bird Areas (IBAs) by Birdlife International. They are the Gilbert Bay/South Arm IBA and the Farmington Bay IBA, which each extend into and cover the undeveloped reaches of the shorelands. These IBAs are of global importance (the highest possible ranking).

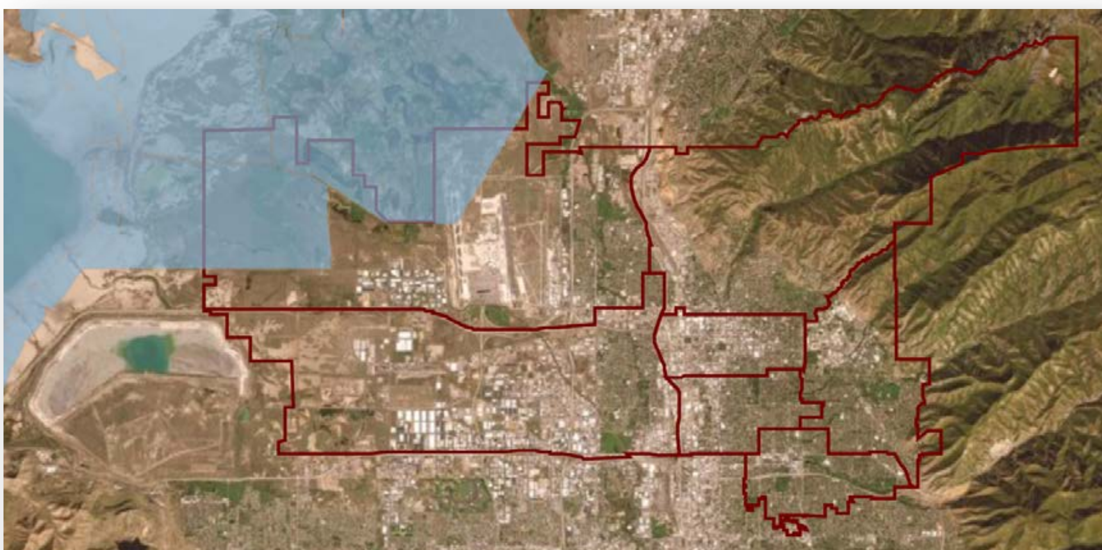


Figure 5. Extent of globally significant Important Bird Areas (blue) in Salt Lake City with City Council districts (red) for reference.

Figure 6. Example of the vegetation of the Jordan River as it winds through Salt Lake City. Image from Google Local Guide Ross Pincock.

2.1.2 Jordan River

The Jordan River is a low-gradient, meandering river that flows north to south through Salt Lake City. Considerable development has affected the banks and floodplain, but recent years have brought attention and restoration efforts to enhance the river, its habitats, and its water quality.

The Jordan River supports riparian (streamside) habitats that are used for nesting by neotropical migratory bird such as Bullock's Oriole, Willow Flycatcher, and Yellow-breasted Chat, all of which nest along the Jordan River and then migrate to Central America for the winter.

The Tracey Aviary conducts surveys and nest monitoring along the Jordan River and birding hotspots along the river include Glendale Golf Course, Jordan River Parkway (200 S to 2100 S), Fife Wetlands Preserve, and Rose Park Golf Course.

Figure 7. Footprint of the Jordan River running south to north through the center of Salt Lake City.

2.1.3 Urban Creeks

Salt Lake City has a series of creeks that flow down from the Wasatch Mountains and cut east to west across the city toward the Jordan River (Figure 7). Over time, the lower extents of these creeks have been undergrounded, cutting off the surface flows and diverting them to underground pipes. For example, City Creek, was undergrounded along North Temple Street in 1909 (Love 2005). These creeks have been the focus of daylighting and restoration activities that may extend into the future (Love 2005). Because of the water flows and support of riparian vegetation, the remaining aboveground creeks remain important habitats for wildlife. They are now surrounded by neighborhoods and receive heavy recreational use and provide valuable access to nature within the urban fabric (Figure 8).

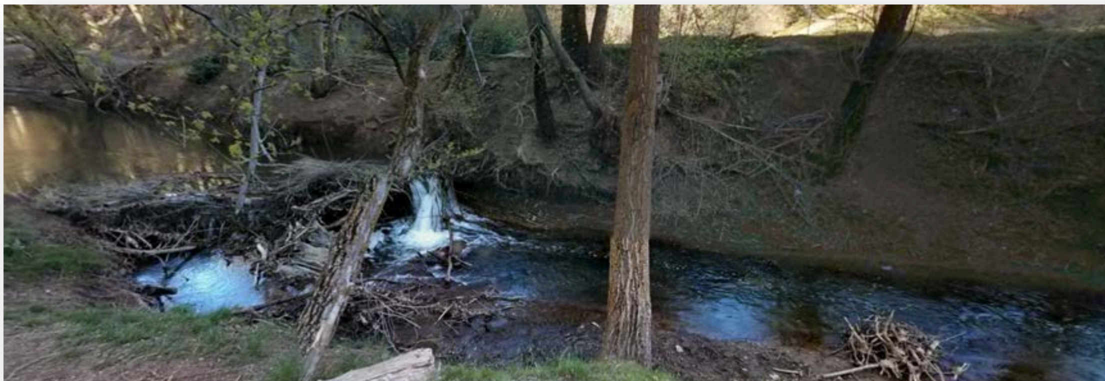


Figure 8. Image of Emigration Creek as it flows through the Wasatch Hollow Open Space. Photo by Google Local Guide Joseph Muhlestein.

2.1.4 Wasatch Mountains

The foothills of the Wasatch Mountains to the west of the Salt Lake City are contiguous with a large block of contiguous open space and wilderness area and therefore are easily recognized as being environmentally sensitive. One of the vulnerabilities of mountainous habitats to light pollution is that their slopes are directly in the light of sight for any light that is emitted upward from nearby sources (Longcore and Rich 2017). Any light from Salt Lake City that is emitted above the horizontal plane and directed toward the east has the potential to degrade the habitats of the Wasatch Mountains.

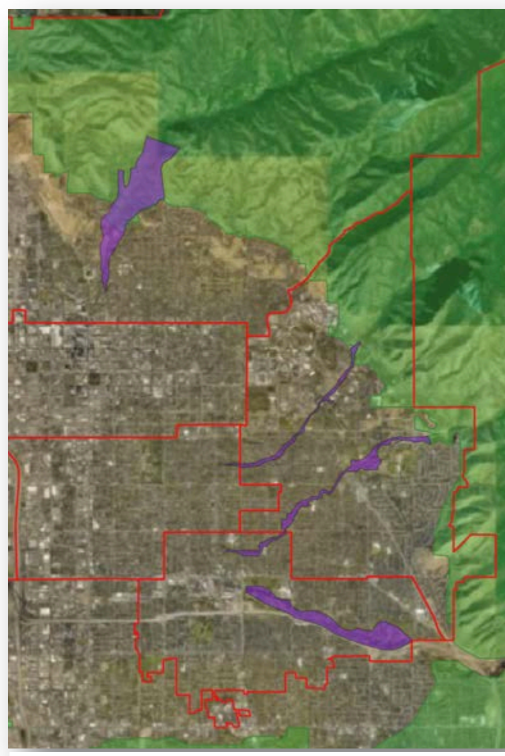


Figure 9. Four urban creeks (purple) extending out of the Wasatch Mountains into Salt Lake City.

2.2 Sensitive Species

Important wildlife species of Salt Lake City were reviewed in a 2010 program for the acquisition of natural lands. The program identified and mapped the distribution of critical habitat for wildlife. A list of species for which potential habitat is found in the City was also provided. This map identified all parcels within the city that intersected with areas that had potential habitat for Black Bear, Bandtailed Pigeon, Blue Grouse, Chukar Partridge, Moose, Mule Deer, Ring-necked Pheasant, Rocky Mountain Elk, Ruffed Grouse, or Snowshoe Hare. The resulting map forms a ring around the core of Salt Lake City, with critical wildlife habitat extending down the slopes of the Wasatch range to the urban edge on the east and also enveloping the shorelands and extending from the west to and around the north of the airport (Figure 10).

The city also has potential habitat for a range of sensitive plant and wildlife species. These species include birds of the open shorelands (Bobolink, Burrowing Owl, Long-billed Curlew, Northern Goshawk, Short-eared Owl) those associated with the foothills and creeks (Lewis's Woodpecker, Three-toed Woodpecker, Greater Sage Grouse, and some found throughout (e.g., Ferruginous Hawk, Grasshopper Sparrow). Other sensitive wildlife species include the Smooth Greensnake, found in the mountains, spotted bat and Townsend's big-eared bat.

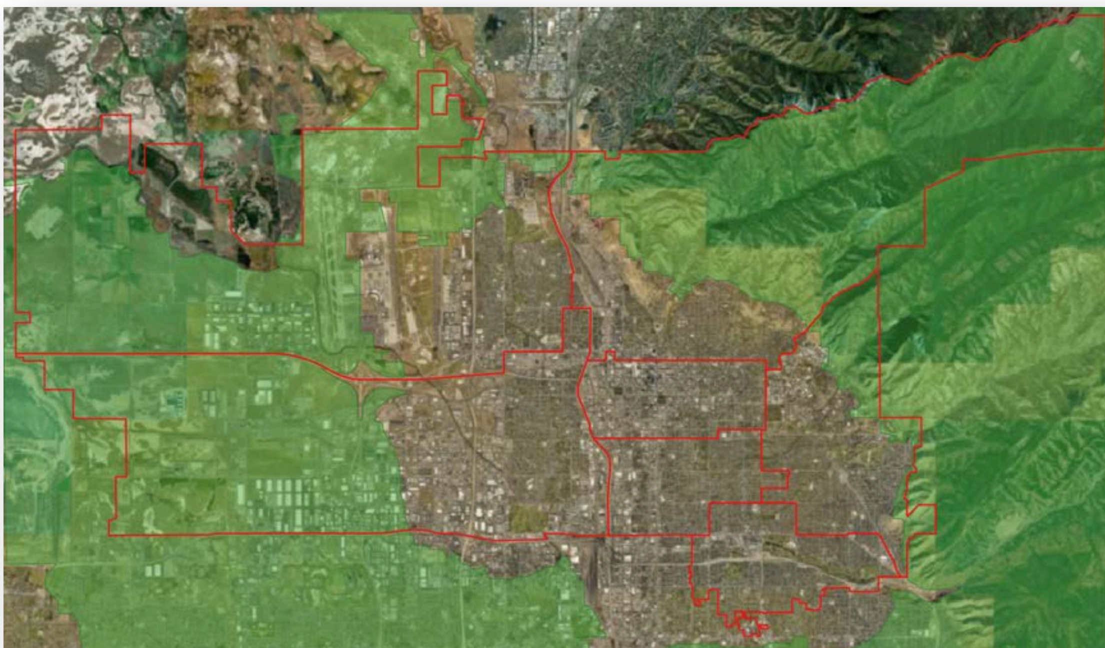


Figure 10. Distribution of parcels (green) that intersect with critical wildlife habitat, with City Council districts for reference.

Other wildlife species, although not recognized formally as sensitive, deserve attention in a street lighting plan intended to reduce and avoid impacts. Fireflies are known to be sensitive to light pollution and have popular appeal as wondrous symbols of the dusk and nighttime environment (Lloyd 2006). The Natural History Museum of Utah is collecting firefly sightings from around the state and has reports from both north and south of Salt Lake City and a few records have been reported from within Salt Lake City.

Bats are also significantly influenced by lighting conditions. Mexican free-tailed bats (*Tadarida brasiliensis*) are well-known to residents because they roost at West High School near downtown during migration. Other documented species include hoary bat (*Lasiurus cinereus*; https://www.inaturalist.org/observations/3742269). It is likely that more species and locations for bat foraging and roosting would be documented if acoustic surveys were conducted (O'Farrell et al. 1999).

2.3 Effects of Lighting on Key Wildlife Groups

Artificial light at night can have a range of lethal and sub-lethal effects on wildlife (Longcore and Rich 2004, Rich and Longcore 2006, Gaston et al. 2012, Gaston et al. 2013, Meyer and Sullivan 2013). Some wildlife species will avoid areas with additional lighting (Beier 1995, 2006, Stone et al. 2009, Stone et al. 2012) or otherwise be adversely impacted (Hölker et al. 2010a, Hölker et al. 2010b, Longcore 2010, Gaston et al. 2013).

The formally recognized sensitive species in Salt Lake City, or at least potentially present, include large and small mammals, migratory and resident birds, bats, one reptile, and at least one plant species. The types of disruption from lighting that could occur for these groups include attraction and disorientation leading to injury or death, disruption of connectivity between habitat patches, interference with predator-prey relations and circadian rhythms that influence foraging decisions, and disruption of pollination.

2.3.1 Attraction and Disorientation

Attraction/repulsion and disorientation are possible outcomes of encounters between wildlife and artificial light at night (Longcore and Rich 2004). The most well-known situation is the attraction and disorientation of hatchling sea turtles on ocean beaches, which results in the death of the juvenile turtles that do not reach the ocean (McFarlane 1963). The two most relevant instances of attraction and disorientation for Salt Lake City are the impacts on migratory birds and on insects.

Migratory Birds. Research with weather radar over the past five years has dramatically improved understanding of the influence of city lights on migrating birds. Most songbird species migrate at night and they can be detected and mapped on weather radar. A massive trove of radar data has been accumulated over the past 25 years and so researchers can now use those data and powerful new computing approaches to understand the influence of lights on the migratory paths of birds.

Light at night escaping upwards so that it can be measured by a satellite is associated with greater numbers of birds present during the day, especially in the fall when juveniles are migrating south (La Sorte et al. 2017). As the birds are migrating southward they are attracted to the lights of the city and then end up disproportionately using habitats in and around cities as compared with potentially better habitats farther from cities (McLaren et al. 2018). Lights can rapidly increase the density of migratory birds in an area at night. A study of the Tribute in Light installation in New York documented an increase from 500 birds within 0.5 km of the vertical light beams before they were turned on to 15,700 birds within 0.5 km 15 minutes after illumination (Van Doren et al. 2017).

Attraction at night is only the first hazard. Urban habitats and especially business districts are quite hazardous to these birds because once they are on the ground, they are susceptible to collisions with glass, which they do not perceive as a barrier (Klem 1990, Sheppard and Phillips 2015). The combination of night-time lights followed by daytime glass exposure is a significant threat to songbirds during the already strenuous migratory period (Cabrera-Cruz et al. 2018).

Radar data have been used to track the relative exposure of migratory birds to lights within U.S. metropolitan areas ranked by area. The Salt Lake City–West Valley City urban area ranks 74th in area among cities in the continental US by area. When evaluated for the number of migrating birds based on radar tracking (average for 1995–2017) and the intensity to light as measured by the VIIRS DNB satellite (average for 2012–2017), the city ranks 120th in exposure for the spring and 112th in exposure for the fall (Horton et al. 2019) (Figure 11). Other cities have far more migratory birds flying overhead per unit area. For example, New Orleans has many more birds flying overhead because of its location on the Gulf Coast, where all of the birds heading to the northern forests and back again to Central and South America funnel overhead.

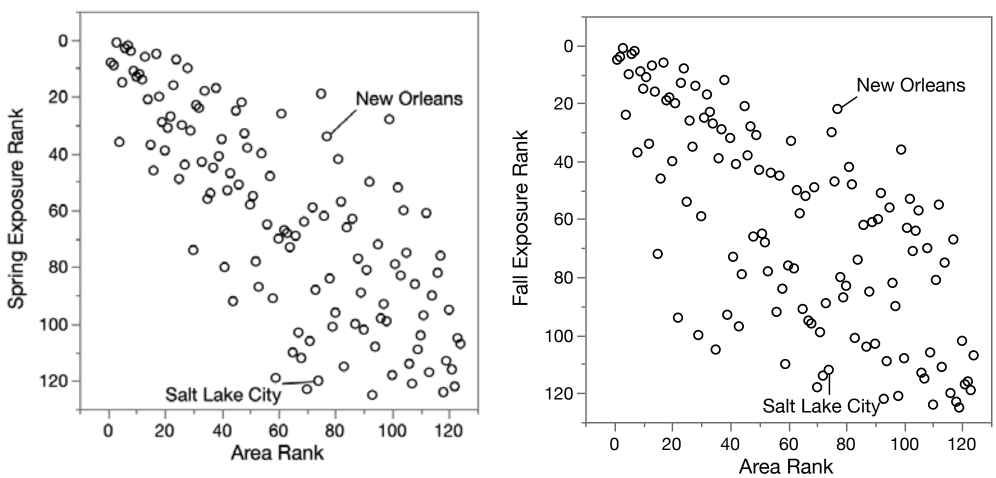


Figure 11. Relative exposure of migrating birds to light in Salt Lake City within the 125 largest metropolitan regions in the United States (Horton et al. 2019). Salt Lake City has relatively fewer migratory bird species overhead during migration than other similarly sized metropolitan regions.

Even though the relative exposure is low compared with other similar-sized cities, birds are attracted to and die at the buildings of Salt Lake City. The city can take a leadership position by reducing the amount of light escaping upward from lighting throughout the city and especially downtown to reduce this unfortunate outcome.

Insects. Many families of insects are attracted to lights, including moths, lacewings, beetles, bugs, caddisflies, crane flies, midges, hoverflies, wasps, and bush crickets (Sustek 1999, Kolligs 2000, Eisenbeis 2006, Frank 2006, Longcore et al. 2015a). Any lamp with significant emissions in the ultraviolet or blue wavelengths is highly attractive to insects (Eisenbeis 2006, Frank 2006, van Langevelde et al. 2011, Barghini and de Medeiros 2012). Insects attracted to lights are subject to increased predation from a variety of predators, including bats, birds, skunks, toads, and spiders (Blake et al. 1994, Frank 2006).

Moths are especially attracted to lights and they play a special role in the ecosystem as pollinators. Moths are killed in collisions with the lights or by becoming trapped in housings (Frank 1988, 2006). Short of death, this attraction removes native insects from their natural environments (Meyer and Sullivan 2013) in what Eisenbeis (2006) calls the "vacuum cleaner effect." Attraction of insects by light results in significant reduction in pollination (Macgregor et al. 2015, Macgregor et al. 2017) and this effect spills over into daytime insect communities because of the decreased seed set and reproduction of plants (Knop et al. 2017).

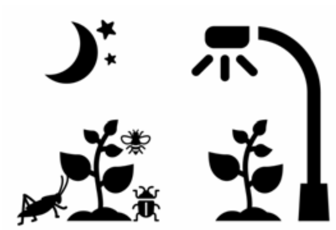
Bats. The responses of different bat species to lighting are complex (Rydell 2006). Some faster-flying and more maneuverable species will be attracted to lights, where they forage on insects also attracted to the lights. Slower and less maneuverable species will avoid lights, essentially being repulsed by their presence (Stone et al. 2009, Stone et al. 2012, Stone et al. 2015). Light at the entrance of a roost can keep bats from emerging for their nightly foraging (Boldogh et al. 2007).

2.3.2 Loss of Connectivity

As is implied by the repulsion of some bat species by nighttime lighting, the presence of permanent outdoor lighting can severe landscape connectivity for wildlife species (Stone et al. 2009). The existence of the lights themselves, shielded or not, is sufficient to influence wildlife movement (Beier 1995, 2006). This phenomenon was illustrated by a radio telemetry study of young mountain lions in Orange County, California (Beier 1995):

> All travel in corridors and habitat peninsulas occurred at night. During overnight monitoring, the disperser usually avoided artificial lights when in the corridor or peninsula. For example, M12 [a juvenile mountain lion] consistently used dark areas as he rapidly (<4 hr) traveled the grassy ridge (6.0 X 1.5 km) separating San Juan Capistrano from San Clemente (Fig. 1). Also M12 seemed to use light cues when he negotiated the tightest part of the Pechanga Corridor; his consistent movements in the direction of the darkest horizon caused him to miss the only bridged undercrossing of I-15.
>
> Overnight monitoring showed that dispersers especially avoided night-lights in conjunction with open terrain. On M12's initial encounter with a well-lit sand factory and adjacent sand pits, he took 2 hours and 4 attempts to select a route that skirted the facility, after which he rested on a ridgetop for 2 hours. During 2 nights in the Arroyo Trabuco, M8 explored several small side canyons lacking woody vegetation. He followed each canyon to the ridgetop, where city lights were visible 300–800 m west. He stopped at each canyon ridgetop for 15–60 minutes before returning to the arroyo, without moving >100 m into the grasslands west of the ridgeline in view of the city lights.

Further data on the use of underpasses and the influence of lighting on landscape connectivity have been reported. An experimental evaluation of underpass use by wildlife found that for mule deer, even nearby lights affected movement compared with a reference period (Bliss-Ketchum et al. 2016). Research conclusively shows that artificial night lighting can have an adverse impact on the foraging behavior of bat species, and exclude certain species from foraging routes or areas (Stone et al. 2009, Polak et al. 2011).



2.3.3 Foraging

Small mammals respond to illumination in their foraging activities. For example, artificial light of 0.3 and 0.1 lux reduced the activity, movement, or food consumption of a cross-section of rodent species (Clarke 1983, Brillhart and Kaufman 1991, Vasquez 1994, Falkenberg and Clarke 1998, Kramer and Birney 2001). This phenomenon also has been shown in natural (in addition to laboratory) conditions (Kotler 1984a, Bliss-Ketchum et al. 2016, Wang and Shier 2017, Wang and Shier 2018).

The driving force behind patterns of activity and foraging by animals influenced by artificial lights is presumably predation. Additional (artificial) light might increase success of visually foraging predators, thereby increasing risk to their prey, with one critical exception: prey species with a communal predator defence, such as schooling or flocking, have decreased risk of predation with additional light. Evidence for this general pattern continues to accrue. Partridge are documented to roost closer to each other on darker nights and can see predators farther away on lighter nights (Tillmann 2009). Some species of bats avoid artificial lights to reduce predation risk (Stone et al. 2009, Polak et al. 2011). A general review of nocturnal foraging suggests that night is a refuge with decreased overall predation on birds and mammals, and that foraging groups are larger at night, especially for clades that are not strictly nocturnal (Beauchamp 2007). Songbirds that were experimentally relocated moved back to their home ranges at night, a result that is most consistent with predator avoidance (Mukhin et al. 2009). Pollination is determined by foraging activities and the distribution of insect foragers, which in turn are susceptible to attraction, disorientation, and other behavioral disruptions from artificial lights (Knop et al. 2017).

Predator-prey systems are tightly tied into lunar cycles, with many relationships affected by lunar phase (Williams 1936, Sutherland and Predavec 1999, Topping et al. 1999, Riou and Hamer 2008, Upham and Hafner 2013). Even within species, variation in color interacts with lunar cycle to affect foraging success. White-morph Barn Owls have an advantage foraging during the full moon because the light reflecting off their white feathers triggers their rodent prey to freeze in place, while Barn Owls with darker colored feathers do not have this advantage (San-Jose et al. 2019). Light pollution can be expected to interfere with such patterns (San-Jose et al. 2019).

Predator-prey relations probably also drive the influence of artificial lighting on bird nest location. The one experimental study of the effect of streetlights on breeding bird density shows a negative impact (De Molenaar et al. 2006). The streetlights in De Molnenaar et al.'s study created a maximum illumination of 20 lux (1.8 footcandles). The adverse effects of these lights (decreased density of Black-tailed Godwit nests) were experienced up to 300 m (984 ft) from these lights, extending into areas with negligible increased illumination, which means that the adverse impact results from the light being visible, rather than the amount of light incident on the sensitive receptor.

2.3.4 Interference with Visual Communication

Artificial light at night affects species such as fireflies that communicate visually at night with light. Although the distribution of fireflies is limited within the city, their recovery could be a laudable urban conservation goal. Artificial light washes out the signals that fireflies use for communication and is potentially contributing to the decline of fireflies and other organisms that rely on bioluminescent communication (Lloyd 2006, Hagen and Viviani 2009, Viviani et al. 2010, Bird and Parker 2014). A Brazilian study documented lower species richness of fireflies in areas of 0.2 lux and greater (even from sodium vapour lamps, which are otherwise considered to be more wildlife friendly), except for those few species that naturally fly at greater illumination (Hagen and Viviani 2009).

2.3.5 Physiological Responses

Birds. The research on the effects of ambient and artificial lighting on bird reproduction goes back to the 1920s (Rawson 1923, Rowan 1938). Birds can be extremely sensitive to illumination, and extension of foraging by species under artificial lights is documented in the literature (Goertz et al. 1980, Sick and Teixeira 1981, Frey 1993, Rohweder and Baverstock 1996). Research shows an earlier start to seasonal breeding of birds in urban (lighted) environments than rural (dark) environments (Havlin 1964, Lack 1965). Many of the physiological impacts of lighting on birds are reviewed by De Molenaar et al. (2006) and Longcore (2010).

- Dawn song in American Robins (*Turdus migratorius*) is influenced by ambient illumination (Miller 2006);
- Dawn song and lay date in a songbird have been shown to be associated with proximity to streetlights, with evidence that this affected mate choice, which has implications for fitness (Kempenaers et al. 2010);
- Light of 0.3 lux can move reproductive seasonality of songbirds by a month and cause irregular molt progression (Dominoni et al. 2013a, Dominoni et al. 2013b);
- Light is a major driver of the daily activity patterns of songbirds (study animal European Blackbird; *Turdus merula*), causing them to be active earlier in the morning (Dominoni et al. 2014);
- A songbird (Tree Sparrow; *Passer montanus*) exposed to 6 lux in the laboratory secreted luteinizing hormone earlier than controls, and urban birds exposed to 3–5 lux exhibited this pattern in the field; both of these response were statistically associated with night lighting (Zhang et al. 2014);
- Artificial light outside of nest boxes affects perceived photoperiod of Great Tits (*Parus major*), which the authors interpret as creating an ecological trap (Titulaer et al. 2012);
- Artificial light rather than traffic noise affects dawn and dusk song timing in common European songbirds (Da Silva et al. 2014).

Artificial night lighting affects diurnal species substantially as well. As noted above, it affects timing of dawn and dusk song, seasonality of reproduction, mate choices, and can extend activities of diurnal species into the night (Stracey et al. 2014). Birds that sing earliest are responding to increases in illumination so faint that they are undetectable by humans (Thomas et al. 2002). This is true for impacts across species, where diurnal species are affected in numerous ways by an altered nighttime environment (Miller 2006, Kempenaers et al. 2010, Titulaer et al. 2012, Dominoni et al. 2013a, Dominoni et al. 2013b, Da Silva et al. 2014, Dominoni et al. 2014, Zhang et al. 2014, Da Silva et al. 2015).

Mammals. Similar impacts on both seasonality and daily rhythms are documented for mammals. For example, lighting from a military base was shown to desynchronize the breeding time of tammar wallabies in the field in Australia, as well as to suppress nightly melatonin production (Robert et al. 2015). Studies on the physiological effects of light at night on mammals are abundant, partly because of the implications for understanding human health (e.g., Zubidat et al. 2007, Zubidat et al. 2010). As a whole, they show that artificial light at levels far less intense than previously assumed are able to entrain circadian rhythms and influence physiological functions such as immune response (Bedrosian et al. 2011). For example, extremely dim light is sufficient to entrain rhythms in mice, and can be done without phase shifting or reducing production of melatonin (other physiological indicators of light influence) (Butler and Silver 2011). For shorter wavelengths (blue and green) entrainment takes place at 10^{-3} lux. Much greater intensity, 0.4 lux, is needed for red light to entrain rhythms (Butler and Silver 2011). This research is consistent with recently documented differences in mice behaviour for exposure to 20 lux vs. 1 lux at night (Shuboni and Yan 2010). Mice that were exposed to dim (5 lux) light at night consumed the same amount of food as those under dark controls, but gained weight as a result of the shift in time of consumption (Fonken et al. 2010).

Plants. Plants "anticipate" the dawn with a synchronized circadian clock and increase immune defence at the time of day when infection is most likely (Wang et al. 2011). The timing of resistance (R)-gene mediated defences in *Arabidopsis* to downy mildew is tied to the circadian system such that defences are greatest before dawn, when the mildew normally disperses its spores (Wang et al. 2011). Preliminary experiments show that carbon assimilation is lower in trees exposed to continuous night lighting, compared with controls in a "stereotypical urban setting" (Skaf et al. 2010). Some plants might use light-triggered circadian rhythms to synchronize expression of anti-herbivory compounds with periods of peak herbivory, leading to increased loss from herbivory in out-of-phase plants (Goodspeed et al. 2012). The importance of circadian rhythms in plants, for everything from disease response and flowering time to seed germination, and the potential for disruption by night lighting, has not been explored widely (Resco et al. 2009, Bennie et al. 2016).

Light at night also affects the perception of seasonal change by plants and their associated physiological responses. Exposure to light at night is associated with earlier budburst in plants in the United Kingdom, in a pattern that cannot be explained by the greater temperatures in cities (ffrench-Constant et al. 2016). Trees exposed to nearby lights have long been observed to hold on to their leaves later in the fall (Briggs 2006, Škvareninová et al. 2017, Massetti 2018) and prevent seed set in plants cued to shorter daylengths (Palmer et al. 2017).

3 Consideration of Spectrum in Municipal Street Lighting Systems

The LED revolution in outdoor lighting has created new possibilities to select the spectral composition of lights. Unlike lighting technology of the past, such as high-pressure sodium or metal halide lamps, the range of colors that can be deployed using LEDs is wide. As a result, it is possible to select spectral profiles that can either reduce or increase the effects of a street lighting system on the visibility of stars in the night sky, on human circadian rhythms, and on wildlife (Longcore 2018).

3.1 Effects on Wildlife

This review of the effects of lighting spectrum on wildlife is drawn from my recent article (Longcore 2018), which can be consulted for additional details.

The effects of lights of different spectral composition on wildlife depends on the responses of different wildlife groups to those lights. A limited number of "response curves" are available that track the response for a species or group of species to light throughout the entire visible spectrum (and into the portion of the spectrum invisible to humans). These curves have been developed for insects in general, bees, moths, juvenile salmon, seabirds, and sea turtles. My colleagues and I have developed methods to compare different lamp types for their effects across these groups (Longcore et al. 2018a).

Some patterns are clear. Insect attraction to LEDs is lower across the board when compared with lamps that emit ultraviolet light. Both "warm" and "cold" LEDs have been compared with metal halide and mercury vapor lamps and found to attract less than a tenth of the number of insects, a finding that is attributable to the difference in ultraviolet emissions (Eisenbeis and Eick 2011). Conversely, most broad-spectrum LEDs used in outdoor lighting do have a potential to adversely impact the perception of daylength (and thus seasonality) in plants, because the peak sensitivity of the phytochromes that detect daylength are in range of LED peak emissions for most full-spectrum LEDs.

Several approaches are available to summarize the quality of light from different sources. One is to use the Correlated Color Temperature (CCT). This metric, although imperfect, is widely used in lighting design. Some jurisdictions that regulating lighting to protect species have a hard cut-off (e.g., no light allowed < 540 nm) or measure the amount of light emitted below certain thresholds. Another possible metric is the degree to which a light interferes with the non-image forming photoreceptors that result in disruption in circadian rhythms in humans, because nearly all vertebrates will have a similar response curve for suppression of melatonin production at night. Drawing on data from Longcore et al. (2018a), the response of different wildlife groups against these possible metrics describing spectrum were plotted (Figure 12). Across all groups, less blue light (shorter wavelengths) resulted in lower effects. As for metrics to describe this pattern, correlation with CCT was strong, but melanopic lux (the brightness of the light as sensed by melanopsin) correlated the best. These results will only hold true for lamps without ultraviolet or violet emissions, however.

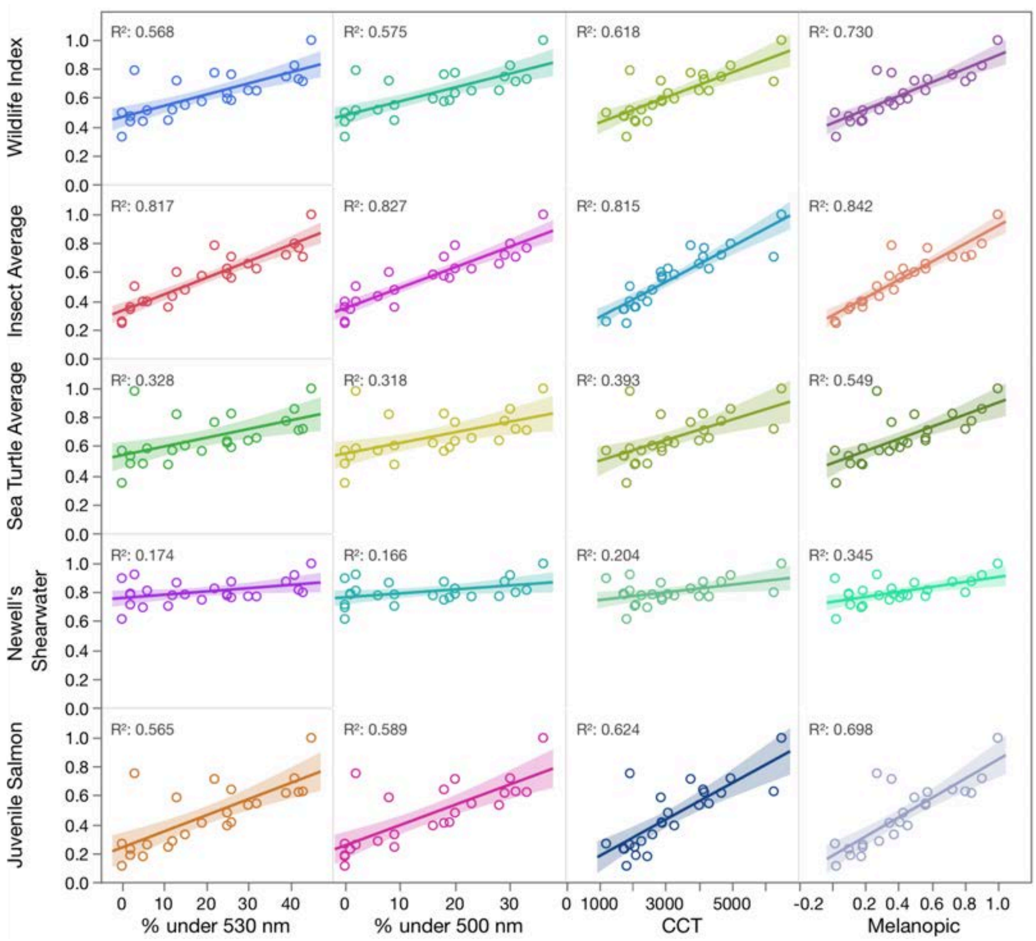


Figure 12: Relationship of modeled effect of lamps on different wildlife species or groups (juvenile salmon, Newell's shearwater, sea turtles, insects, and their average) with percent emissions <530 m, % emissions < 500 nm, correlated color temperature (CCT), and melanopic power of the lamps. Data from (Longcore et al. 2018b).

CCT is not a perfect predictor of effects on wildlife, but it is a reasonable rule of thumb that lower CCT will be less disruptive to wildlife and we already know that it will be less disruptive for circadian rhythms and astronomical observation (Aubé et al. 2013). The lamps with the lowest projected influence on wildlife overall were low pressure sodium (which is being phased out), high pressure sodium, PC amber LEDs, and filtered LEDs (Figure 13).

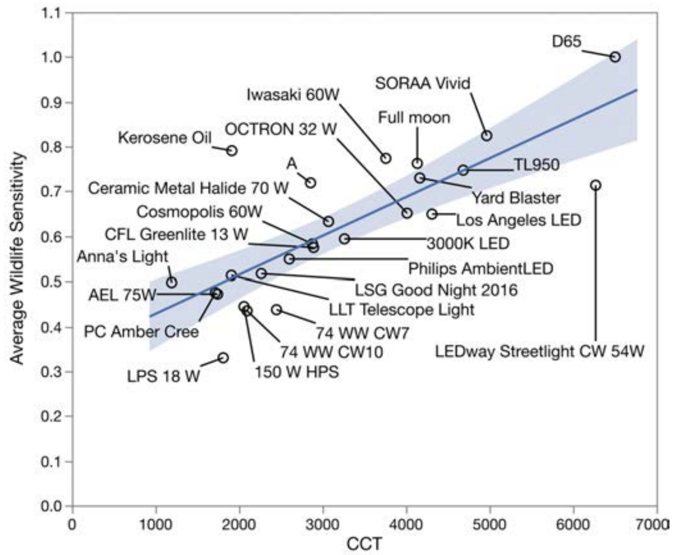


Figure 13: Relationship of correlated color temperature to average wildlife sensitivity with lamps and illuminants labelled. Data from (Longcore et al. 2018b).

These results represent the predicted effects of the lamps on wildlife. To account for preferences in outdoor lighting, another ranking was created that incorporated a penalty for low color rendering index (CRI). Any lamp with a CRI over 75 was assumed to have adequate color rendering, while those with lower CRI were penalized in the overall index. The resulting ranking of lamps is notable in that low pressure sodium ranks lower because of its extremely low CRI, while PC Amber and filtered LEDs rank the highest, balancing both lower wildlife impacts with reasonable if not high CRIs (Figure 14).

As a rule of thumb, CCT can be used as an indicator of wildlife effects, but this may not hold true across all applications. Migrating birds cannot orient under red light and therefore solid red lights are to be avoided on communication towers (Longcore et al. 2008). Green light has support for minimizing attraction of nocturnal migrant birds (Poot et al. 2008). Many other special cases exist and would require consultation with experts on a taxonomic group or species at risk. For the species of concern in Salt Lake City, however, including insects as indicators of riparian health, bats, and nesting birds, lower CCT will decrease ecological impacts when combined with other good street lighting practices (low glare, no uplight, appropriate intensity, and only lighting when warranted).

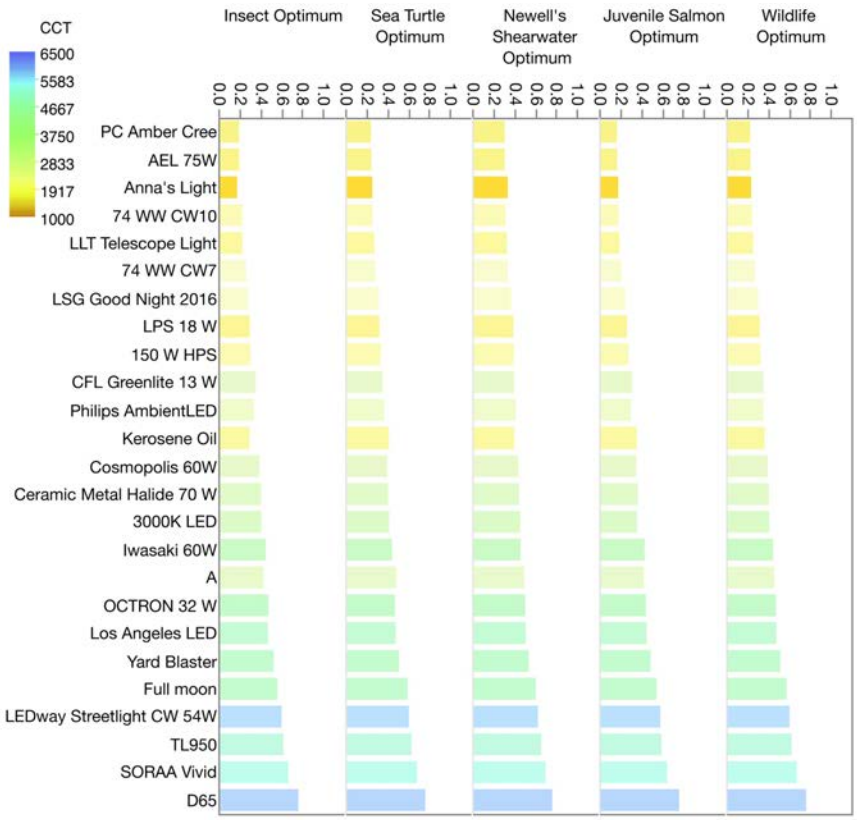


Figure 14: Ranking of lighting sources that equally weights wildlife response, melanopic response, astronomical light pollution (Star Light Index (Aubé et al. 2013)), and Color Rendering Index. Reprinted from (Longcore et al. 2018b). Shorter bars represent a combination of lower wildlife responses and higher CRI.

None of the effects measured with these metrics addresses the scattering of light in the atmosphere, but tools to evaluate the effects of different spectra on astronomical light pollution are available to do that.

3.2 Effects on Dark Skies

The introduction and widespread adoption of 4000K and greater LED streetlights poses a significant threat to astronomical observation and the quality of the night sky as a recreational amenity. It is well-established that the preponderance of light at shorter wavelengths found in high color temperature LEDs scatters more in the atmosphere and if replacing high-pressure sodium lamps with similar intensity and shielding, will result in degradation of the night sky (Kinzey et al. 2017). The effects of the adoption of high color temperature LEDs were quickly noticed and documented by night sky advocates, who could see the degree to which full-spectrum white lights adversely impacted the aesthetics of the night sky when compared with lower color temperature high-pressure sodium systems (Figure 15).

Figure 15. View eastward from Antelope Island State Park, showing visible effect of spectrum on night sky aesthetics. Photo from park's application to become recognized as a Dark Sky Park by the International Dark-Sky Association (2017).

Although the U.S. Department of Energy originally paid little attention to the adverse environmental impacts of high-color temperature LEDs, focusing instead solely on energy savings, it has recently returned to this question and issued a report (Kinzey et al. 2017) investigating the role of lamp spectrum in degradation of the night sky, measured as sky glow.

Rather than focusing solely on spectrum, the report investigates the influence of associated variables that are commonly adjusted in the process of converting from older lighting technology to LEDs. For example, it is common for older lamps to have a drop lens below the lamp that results in a portion of the light being reflected upward, above the horizontal plane from the lamp. It has also become increasingly common for full-spectrum LEDs (e.g., at CCT 2700–4200 K) to be reduced in measured intensity for daytime (photopic) vision when compared with the high-pressure sodium lamp that the LED is replacing. Such reductions in intensity result from complaints from residents that the new LEDs, although producing the same (photopic) illumination (in lux) as the HPS, are perceived as far brighter because they intersect more with the sensitivity of human dark-adapted (scotopic) vision. It is therefore often possible to reduce the intensity of LEDs (measured in photopic lux) compared with HPS and still achieve equal or greater visibility.

The study modeled the effects of different combinations of spectrum, uplight, and intensity under different weather conditions, human vision adaptation levels, and distance from the lights. For the purpose of illustration, the nearby viewer results are reproduced here (Figure 16). These results compare high-pressure sodium as the baseline, with PC Amber LED (1872 K), and 2700–6100 K LEDs. When compared on an equal basis for other factors (same uplight and intensity), only the PC Amber produced roughly equivalent light pollution compared with HPS and all full-spectrum LEDs produced significantly more light pollution, especially when considering human night vision. When both HPS and LEDs were assumed to have 0% uplight and the LEDs were set at half the intensity of the LEDs, then LEDs with CCT < 3000 K were comparable to or produced less light pollution than HPS. Results were similar with HPS at 2% uplight and LEDs at 0% uplight and 50% intensity.

The take-home message of this research for the Salt Lake City street lighting master plan is that for LED lamps lights to reduce light pollution compared with the previously common HPS lamps, they must be 0% uplight, 50% less bright, and with a CCT of no greater than 3000 K. The minimum impact on light pollution could be achieved with PC Amber or comparable filtered LEDs that produce a similar CCT as HPS (~ 1800 K).

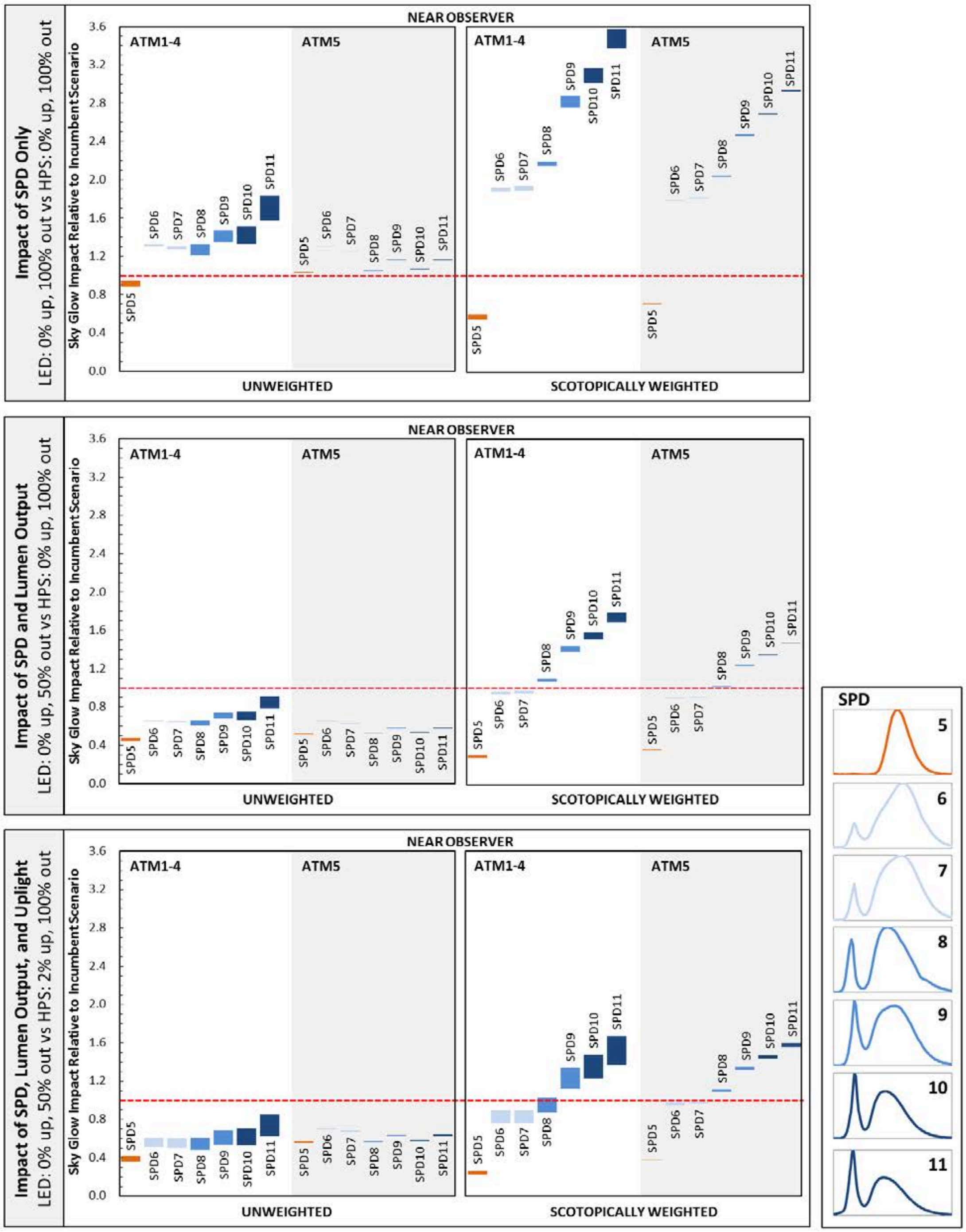


Figure 16. Comparison of light pollution from different LED spectral power distributions (SPDs) with light pollution from a high-pressure sodium light (horizontal dotted red line). SPDs (see right): SPD5: 1872 K (PC Amber), SPD6 = 2704 K, SPD7 = 2981 K, SPD8 = 3940 K, SPD9 = 4101 K, SPD10 = 5197 K, SPD11 = 6101 K.

3.3 Human Circadian Rhythms

It is only in the last twenty years that the mechanism by which light affects human circadian rhythms has been discovered (Berson et al. 2002). The human eye has non-image forming retinal ganglion cells that detect light and perhaps contribute to perception of brightness but not to discerning objects (Hattar et al. 2002). The pigment that detects the light is called melanopsin and it differs in its sensitivity to light from the rods and cones that humans use for vision (Brainard et al. 2001, Schmidt and Kofuji 2009). The peak sensitivity of melanopsin is around 480 nm, in the middle of the blue portion of the spectrum.

Evidence is strong that chronic exposure to light at night increases risk of cancer, diabetes, obesity, and heart disease (Fonken and Nelson 2014, Bedrosian et al. 2016, Lunn et al. 2017). The question for human circadian impacts from outdoor lighting is whether the exposures are bright enough and whether time of exposure is sufficient to affect circadian rhythms.

Circadian rhythms can be affected by light in many pathways. The first pathway is suppression of melatonin through exposure in the evening, especially after dusk. This exposure could be indoors or outdoors, either in the sleeping habitat or not. Dose-response curves for light exposure and melatonin suppression have been developed and it is the basis for the definition of Circadian Light (Rea et al. 2010). The second pathway is through sleep disruption through exposure to light in the sleeping habitat, even if the light levels are insufficient to suppress melatonin. Lack of sleep and reduced long wave sleep, which is critical to recovery and repair (Cho et al. 2016), can result from disturbance glare, as anyone ever awakened by moonlight can attest.

It remains an open question whether indoor exposure to street lighting is of sufficient magnitude to affect circadian rhythms directly, but recent research investigating light spectrum and cancer risk suggests that the color of light outdoors in the vicinity of residences is an important risk factor (Garcia-Saenz et al. 2018).

The influence of outdoor lighting on sleep has been investigated through epidemiological studies that measure exposure using satellites, epidemiological studies using portable individual-level measuring devices (comparing with satellite measures), and experimental studies in humans.

A set of studies from Haim, Kloog, Portnov, and colleagues provided correlational data connecting satellite-measured light at night from the DMSP OLS system to breast and prostate cancer, indicating a connection between outdoor lighting levels and rates of these cancers (Kloog et al. 2008, Kloog et al. 2009a, Kloog et al. 2009b, Kloog et al. 2010, Kloog et al. 2011, Haim and Portnov 2013). Similar studies have reinforced these findings in different populations around the world (Bauer et al. 2013, Hurley et al. 2014, James et al. 2017).

Studies investigating sleep as the outcome also find an association with satellite-measured outdoor lighting. For example, those in the higher exposure to light at night in South Korea as measured by DMSP were 20% more likely to sleep less than 6 hours per night and on average slept 30 minutes less than subjects in areas with lower outdoor lighting levels (Koo et al. 2016). In a study in the United States, higher levels of outdoor lighting as measured by DMSP was significantly associated with reporting < 6 hours of sleep per night, an effect that remained in place even after accounting for noise and population density (Ohayon and Milesi 2016). In this study, people who lived in the brightest areas were more likely to go to bed later, get up later, and sleep less. They also were more likely to report that they were dissatisfied with sleep quality or quantity and to be sleepy during the day. DMSP-measured light at night was negatively associated with restorative long wave sleep. Importantly, this study validated that brightness in bedrooms correlated positively with satellite-measured outdoor light (Ohayon and Milesi 2016).

Satellite-measured light at night was also associated with the use of more drugs for insomnia in a second South Korean study (Min and Min 2018). Residents living in the lowest two quartiles of light at night as measured by DMSP used significantly less insomnia medication, even after accounting for age, sex, population density, income, body mass index, smoking status, alcohol consumption, exercise, and psychiatric disease. Mean use of insomnia medication increased with each quartile of light exposure from lowest to highest for each of three insomnia medications (Min and Min 2018).

Most recently, a study of the NIH-AARP Diet and Health Study cohort in the United States investigated sleep and exposure to light at night as measured by the DMSP satellite (Xiao et al. 2020). The highest levels of light exposure associated with 16% (women) and 25% (men) increased probability of reporting short or very short sleep duration. Probability of reporting short or very short sleep increased from lowest to highest quintiles of light at night in models that adjusted for age, race, marital status, state of residency, smoking, alcohol, vigorous physical activity, TV viewing, and median home value, population density and poverty rate at census tract level (Xiao et al. 2020). The authors concluded that, “Taken together, these findings suggest that the prevalence of sleep deficiency is higher in places with higher levels of LAN [Light at Night]” (Xiao et al. 2020).

While studies using remotely sensed data detect associations between sleep disturbance, circadian disruption, and associated diseases and light at night, others question the relationship between outdoor lighting and indoor exposure to light at night. Leaving aside the point that outdoor exposure to lighting can also contribute to circadian disruption, these studies focus on relationships between indoor and outdoor exposure. Recent work confirms the relationship between ground-level irradiance outdoors and satellite-based proxies for light at night. Using a dataset or 515 ground-based measurements of illumination from the upper hemisphere, Simons et al. (2020) showed that ground-based light exposure correlates highly with remotely-sensed light (VIIRS DNB annual composite) and even more with the New World Atlas of Artificial Night Sky Brightness (Falchi et al. 2016). This work conclusively establishes that satellite-measured light at night is a proxy for ambient light in the environment on the ground at night, as one would expect.

With this relationship now established (Simons et al. 2020), in retrospect the individual-level studies of correlation between indoor light levels and satellite-measurements of light at night are testing whether increased outdoor light levels correlate with higher indoor light levels and documenting what those indoor levels might be. Along these lines, Rea et al. (2011) used a Daysimeter device with a resolution of 0.1 lux and found that DMSP measurements had “no apparent relationship” with personal-level exposure. The study concluded that outdoor lighting could have little effect on circadian rhythms in their study population of teachers in upstate New York, basing this conclusion on the assumption that measurable melatonin suppression would be needed to cause sleep disruption. That is, they assume that light equivalent to a full moon shining into a sleeping environment cannot affect sleep or circadian rhythms, which is a dubious assumption. In a more recent Dutch study, individual-level light exposure for children was measured indoors with a device that had a resolution of 0.1 lux (Huss et al. 2019). They found an influence of outdoor light on indoor light during the darkest time period with a correlation of 0.31. It should be noted, however, that 94% of the children in the study had curtains that controlled light entering the room. In a survey of lighting designers using their own light meters, Miller and Kinzey (2018) reported measurements in a number of different contexts within homes. At windows without drapes a maximum of 20 lux was reported, with a mean of 5 lux and median of 0.5 lux. All of these dramatically elevated above natural conditions (a full moon would produce 0.1–0.2 lux).

Experiments that involve exposures to light at night document illumination levels that affect health and sleep outcomes. Sleeping under 5 lux of 5779 K light caused more frequent arousals, more shallow sleep, and more REM sleep (at the expense of long wave deep sleep) (Cho et al. 2016). Light greater than 3 lux during the last hour of sleep was associated with weight gain in an elderly population (Obayashi et al. 2016). In another study of an elderly population, increased light at night and especially light at night > 5 lux was associated with 89% increased risk of depression (Obayashi et al. 2013). Further studies indicate that elevated illumination is associated with higher blood pressure as well, with associated excess deaths, at 3, 5, and 10 lux exposures (Obayashi et al. 2014). Metrics of sleep quality (efficiency) were also consistently lower with higher illumination at each category (3, 5, and 10 lux) (Obayashi et al. 2014).

Taken together, this research is consistent with a few different interpretations of the influence of outdoor lighting on human circadian rhythms and health outcomes. It is possible that the correlations between light at night and adverse health outcomes indicate instead variation in another factor, such as air pollution, as suggested by Huss et al. (2019). The robustness of sleep disruption correlations when controlling for population density, however, argues against that interpretation (Ohayon and Milesi 2016). Xiao et al. consider this question and conclude: "[I]t is also possible that the observed associations in our study population represent a true relationship, but primarily driven by individuals whose ALAN exposure was more heavily influenced by outdoor ALAN (e.g. individuals living in rooms facing bright streets and/or with insufficient window treatments to block out light, or individuals with a high amount of nighttime activities outside home)." Such an interpretation, that outdoor light can influence indoor sleeping environments and associated sleep and health outcomes, is consistent with the literature as it currently stands.

Accepting a plausible argument that outdoor lighting affects human sleep in at least some contexts that depend on factors associated with socioeconomic status, the following areas of concern follow for design of a street lighting system.

First, attention should be paid to minimize direct glare into windows of any habitable structure. One cannot assume that people only sleep in bedrooms; residents challenged by housing costs often use many rooms in apartments and houses for sleeping environments and the safest assumption is that any room in a residence might be used for sleeping. The assumption should also not be made that all residents have or can afford blackout shades or curtains. This becomes an issue of environmental justice; circadian disruption is exacerbated in low income communities

(Xiao et al. 2020), presumably because the same amount of light results in more impact because of a lack of capacity to block light.

Second, circadian responses that result from melatonin suppression are heavily dependent on the spectrum of light. As light is concentrated closer to the wavelengths of peak sensitivity for melanopsin, the intensity of light (measured in lux) required to suppress melatonin decreases (Grubisic et al. 2019). At 424 nm, the minimum illuminance for melatonin suppression is 0.1 lux (Souman et al. 2018). The relative impact of different lighting sources can be predicted using the melanopic response curve (Aubé et al. 2013, Longcore et al. 2018a). To illustrate this approach, the melanopic power of lamp sources was standardized to compare with high pressure sodium (HPS; Figure 17). All full-spectrum LED sources have a greater potential circadian impact than HPS, including 2200 K (1.5 times HPS), 3200 K (2.5 times HPS), and 4300 K (3 times HPS).

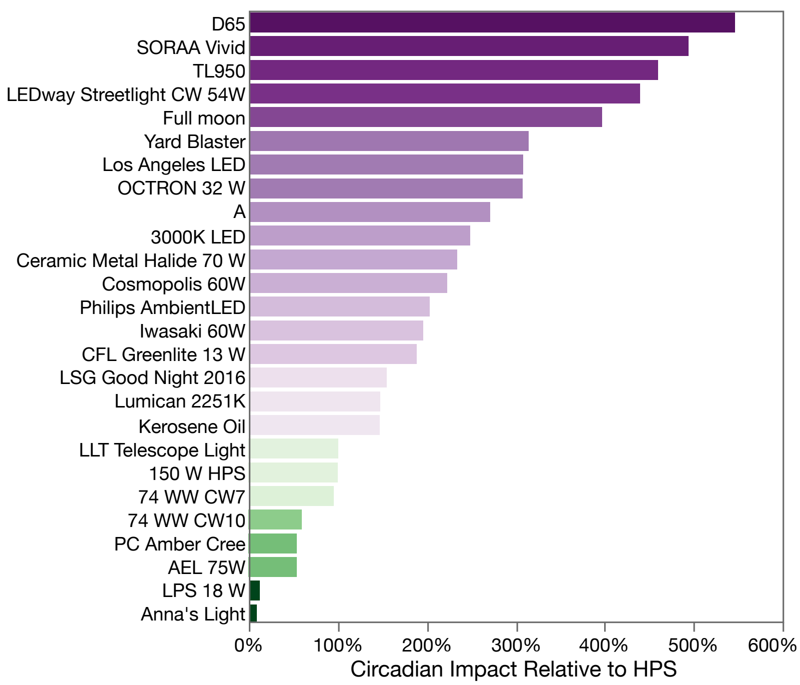


Figure 17. Ranking of light sources by melanopic response (i.e. potential for circadian disruption), compared with a typical High Pressure Sodium (HPS) lamp. Green colors have equal or less melanopic response per lux, while purple colors have more melanopic response per lux than HPS.

The sources that would have the lowest circadian impact are filtered LEDs that avoid the blue portion of the spectrum almost entirely, or PC amber LEDs that do the same. Calculations have not been done to compare LEDs at 50% intensity as has been done for astronomical light pollution impacts. It is reasonable to assume that a similar result would be obtained, with a reducing 50% in intensity for a ~3000K LED compared with HPS bringing it into parity with the potential circadian disruption potential of HPS.

Third, planning for a healthy circadian environment should recognize high variation between individuals in their sensitivity to light, including a 50-fold variation between people in melatonin response to light exposure (Phillips et al. 2019). Children are more sensitive to disruption from light at night than adults (Nagare et al. 2019). Office workers exposed only to dim light during the day are more sensitive to disruption from light at night than those who work outside. Men are more sensitive to light at night, including decreased "long sleep" with increased exposure (Xiao et al. 2020). Some individuals are debilitated by the visual glare from LEDs that are not properly directed and diffused (Ticleanu and Littlefair 2015).

A fair and equitable lighting design approach would recognize a need to accommodate the most sensitive individuals in society in a manner that still allows lighting to achieve its goal of providing a safe environment for pedestrians, cyclists, and people in vehicles. Because some of the medical conditions that are exacerbated by glare may be considered disabilities, it furthermore might be a prudent risk management step to explicitly incorporate these concerns in design to ensure compliance with the Americans with Disabilities Act. Published studies thus far have not shown a decrease in traffic accidents associated with conversion to full-spectrum white LEDs (e.g., >2700 K) (Marchant et al. 2020). Total pedestrian and cyclist deaths in Los Angeles have increased since conversion from HPS to 3000–4300 K LEDs in 2009.[1] Whatever marginal benefits might be associated with higher CCT street lighting, they have not been sufficient to result in significant decreases in accidents that have been documented in published studies. Although a full cost-benefit analysis is beyond the scope of this report and should be the subject of future research, a prudent approach to balance these human health and safety issues is to: use the lowest CCT deemed acceptable, specify high-quality optics to ensure delivery of light on desired surfaces instead of as glare, and avoid light trespass onto windows of any residential property.

[1] See https://la.streetsblog.org/2019/10/29/vision-non-zero-the-human-and-financial-toll-of-los-angeles-dangerous-roads/

4 Design Strategies for a Healthy Nocturnal Infrastructure

With the adoption of a Street Lighting Master Plan, an opportunity arises to reduce unwanted outcomes from outdoor lighting that might include degradation of the experience of the night sky in the region, disruption of human circadian rhythms, and interference with behavior of sensitive wildlife species within the city. Strategies are available to reduce these impacts, some of which can be implemented at all locations where street lighting is warranted, and others that could be applied in zones with sensitive resources or known adverse impacts.

4.1 Systemwide Approaches

Reducing the adverse effects of artificial light at night is a matter of ensuring that the light is away enough for the identified need, but not more.

4.1.1 Need-based Lighting

In defining the terms under which street lighting is warranted, consideration should be given in all instances to the threshold for need to ensure that the installation is supported by verifiable benefits. The need for lighting at night is in part a subjective judgment based on human feelings, so equal consideration should be given to those who are more comfortable with less light as to those who desire more light and final determinations made through a transparent and fair process that evaluates the costs and benefits.

4.1.2 Shielding and Directionality

For all of the reasons discussed in this report, lights should be directed toward their intended targets (mostly roads and sidewalks) and not upwards or into other locations where sensitive receptors might be present (e.g., bedroom windows, habitats). This consideration will usually be built into a modern street lighting plan through specification of luminaire performance in terms of backlight, uplight, and glare. Uplight should be assiduously avoided throughout the system. This step alone will significantly reduce the current contribution of Salt Lake City to light pollution in the region as viewed from the surrounding open spaces and natural lands.

4.1.3 Intensity, Dimming, and Controls

Any time a natural environment is experiencing illumination greater than the full moon (>0.1 lux), or even greater than a quarter moon (0.01 lux), one can assume that species are being affected. This is the case because many species show lunar cycles in behavior, often driven by predator–prey relationships that can be interrupted by elevated illumination (Price et al. 1984, Daly et al. 1992, Upham and Hafner 2013). For example, light as dim as 0.01 lux can inhibit foraging by small rodent species (Kotler 1984b).

Strategies that could be deployed around light intensity across the street lighting system include setting the maximum intensity of lights lower, dimming or extinguishing lights according to a pre-set schedule, and use of programmable and flexible controls to adjust intensity in response to need.

1. If full-spectrum LEDs are to be used (e.g., 2700K, 3000K), then the intensity must be at least half of that measured (in lux) for high pressure sodium to avoid increased light pollution impacts. Lower color temperature LEDs (e.g., 1800K, 2000K, 2200K) would require testing to set the maximum operational intensity to achieve system objectives.
2. Regularly programmed dimming or shut-off is a possibility for the system. Part-night lighting, where lights are shut off after a curfew is an improvement over whole-night lighting for bats but not adequate to reduce all impacts (Azam et al. 2015, Day et al. 2015). For the whole system in Salt Lake City, a dimming schedule, especially for residential areas, that reduced output from (for example) midnight to 5 a.m. seems feasible and would reduce overall contribution to regional light pollution, reduce human circadian disruption, and save energy.
3. Controls can be used as a complement to a lower overall intensity setting. When additional illumination is needed, in coordination with City officials, lighting levels can be increased during the period of the need and then reduce to the "normal" level. Controls can also be used on a neighborhood by neighborhood basis to find the illumination level that is most consistent with and useful within the character of the neighborhood.

4.1.4 Spectrum

The unwanted impacts of the street lighting system would be minimized by using the lowest possible CCT for the most lights in the system. For wildlife, human health, and preserving dark skies, the preferable choice would be lamps with CCT <2000K. Other considerations lead to the use of higher color temperatures in some zones, but the lower the color temperature can be kept on average, the greater the environmental benefit.

Low CCT lights are commercially available. For example, Signify makes 1800K cobra-head street lights (StreetView, RoadView, EcoForm, RoadStar) and decorative models as well (Domus, MetroScape, UrbanScape, LytePro). Cyclone produces a 1800K street light, as does Ignia Light (Figure 18). SNOC provides a 2200K light that mixes white and amber diodes, as does Ignia Light (Figure 19). Lumican also sells a range of street light luminaires that include 1700K through 2200K. RAB lighting sells a 2000K luminaire (Triboro) to match the color of HPS (https://www.rablighting.com/feature/led-roadway-lighting-triboro; Figure 20). Siteco sells 1750K, 1900K and 2200K street lights. CWES builds luminaire systems that use a warm white LED and a filter to avoid blue light emissions while keeping lumens per Watt high in comparison with 2700K and 3000K LEDs (Figure 21). Some communities in Utah are even manufacturing their own filters to protect the night sky and the tourism industry associated with it (Figure 22).

Where full-spectrum light is desired for aesthetic reasons or other considerations, it should in no instance exceed 3000K and preferably not 2700K. Lower CCTs should be considered for residential neighborhoods citywide as acceptable to City officials and residents.

Figure 18. Application of PC Amber lights by Ignia Light.

Figure 19. Demonstration of mix of white and amber diodes to produce 2200K light for a roadway application by Ignia Light.

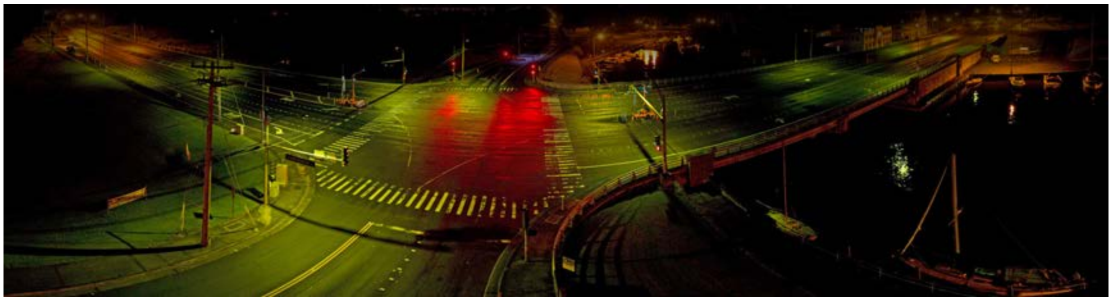


Figure 21. C+W Energy Solutions provides filtered LEDs that use with a warm white LED and filter blue light, resulting in a greenish yellow color that contrasts with yellow light of stop lights.

Figure 22. Ivins, Utah is using filtered LEDs to protect the night sky (https://www.kuer.org/post/fast-growing-southwest-utah-one-city-organizes-protect-night-sky#stream/).

4.2 Ecological Overlay Strategies

In addition to systemwide strategies, which would be implemented throughout all instances of land uses and road segment conditions (e.g., roadway type and associated land use combinations), several ecological overlay strategies would be appropriate that recognize the sensitive natural resources of Salt Lake City. These strategies are tailored to geographic regions where modifications to the light specifications could be used to reduce unwanted environmental impacts.

Each of these strategies is based on a geographic footprint. Spatial data to delineate these regions were either obtained from custodians of those data or digitized by hand based on aerial photograph interpretation. These data sources include:

- Important Bird Areas (from National Audubon Society spatial data webserver);
- Bird Collision Survey Zone (digitized from map provided by Tracy Aviary);
- Parcels that intersect with Critical Wildlife Habitat (digitized from Salt Lake City open space acquisition plan);
- Jordan River Habitat Zone (digitized from aerial photograph interpretation of natural habitat);
- Urban Creek Zone (digitized from aerial photograph interpretation of natural habitat); and
- Community Parks and Neighborhood Parks (from Salt Lake City spatial data webserver).

The digitized habitat zones could be revised with field checks. The purpose of these layers is only to classify roadway lengths for lighting strategies and should not be interpreted as a precise mapping of habitat values.

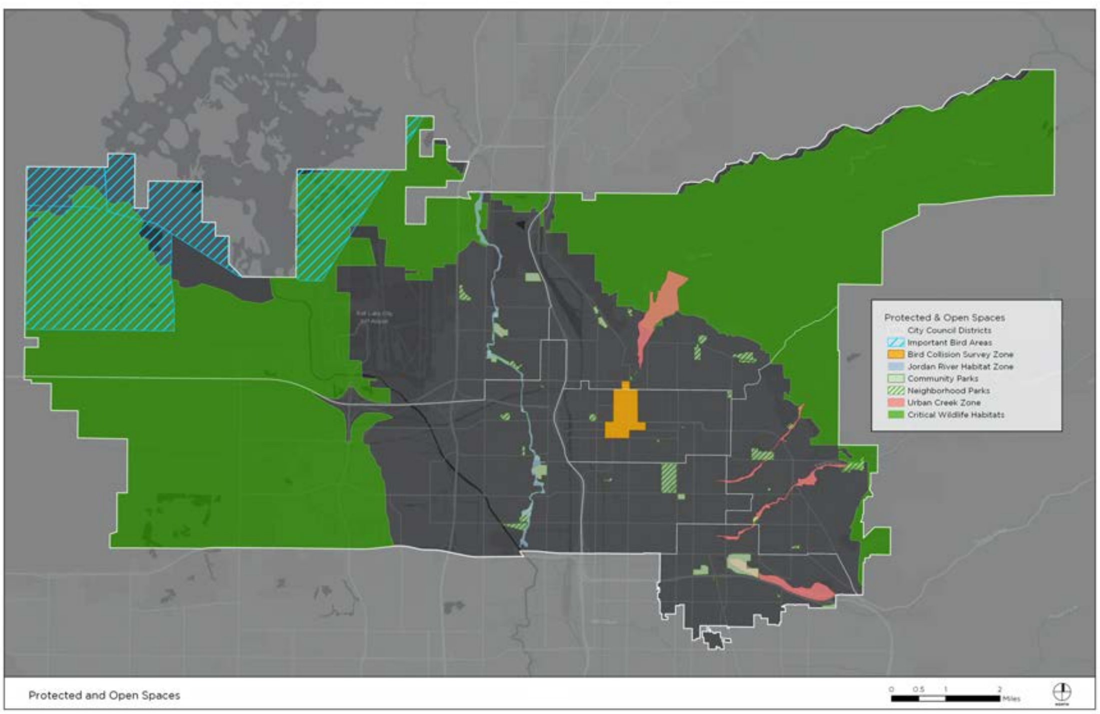


Figure 23. Zones considered for ecological lighting strategies.

A set of additional guidance to reduce impacts that are targeted to the resources in each of these zones is proposed (Table 1).

Table 1. Strategy matrix for ecological overlay zones and major land uses.

Strategy	Uplight	Spectrum (CCT K)	Dimming	Part-night lighting	Intensity (of HPS lumens)
Commercial / Bird collision zone	0.02	≤3000	During migration	No	50%
Critical Wildlife Habitat	0	≤2200K	No	No	50%
Community Parks Natural Lands	0	≤2200K	No	Yes	50%
Jordan River	0	≤1900K	No	Yes	50%
Urban Creeks	0	≤1900K	No	Yes	50%

4.2.1 Bird Collision Zone

The area which is currently monitored for bird collisions is found in the central business district. It is also the brightest location when observing the region from space. Mortality of birds results from the mixture of lights that attract nocturnally migrating birds with the presence of tall buildings with large expanses of glass with which bird collide. The lights draw the birds in and then the glass kills them (Sheppard and Phillips 2015). Current lighting in this zone includes many decorative lights that are not yet shielded to direct light downward. The high lighting levels provided in a commercial zone with the lack of shielding explains the brightness of this area from above at night. Recognizing the need for lighting appropriate for a commercial business district and its level of activities leads to a suggestion of compromise for lighting. Rather than proposing no uplight, even reducing uplight to 2% would represent a dramatic improvement over existing conditions. If no uplight is possible, it would be preferable. Color temperature in this area, and other commercial zones, should be capped at 3000 K. Intensity of lights should be set to 50% of that measured for previous high-pressure sodium lamps to account for human sensitivity to 3000 K lights. With full controls available for the system, a dimming program could be further implemented during peak migration periods (April/May and September/October). If only one period is chosen, it should be fall because the fall migration includes all of the young of the year, which are especially susceptible to collision. Such additional dimming could be implemented either all night or after midnight or another set time. For this area, actions on the part of the City might catalyze participation in mitigation approaches by property managers (Light Out Salt Lake organized by the Tracy Aviary); turning lights out inside buildings at night would further reduce attraction of birds and resulting mortality.

4.2.2 Critical Wildlife Habitat Zone

The region that intersects with parcels containing critical wildlife habitat is found in the foothills to the east of downtown and then in the flat shorelands to the west. The western area also includes the two globally significant Important Bird Areas. Because this zone contains a range of land uses, including commercial, industrial, and residential areas, the proposal is to match the low color temperature of previous lighting systems (e.g., 2000–2200 K) with full cut-off lighting to reduce impacts on nearby sensitive resources. This lower temperature is especially important near the Great Salt Lake, which is a source of fog (Hill 1988). Fog is extremely efficient at reflecting light and recent research has shown that foggy conditions result in a 6-fold increase in night sky brightness (a measure of light pollution) (Ściężor et al. 2012). Fog also scatters light down into habitats. Full cut-off lighting at a low enough color temperature to allow reasonable color rendering should balance the needs of the land uses in these zones with the sensitive resources found there.

4.2.3 Jordan River and Urban Creeks

The Jordan River and the urban creeks cut through the street grid such that they intersect with only a few street lights along any given segment. It might therefore be possible to minimize impacts to these riparian zones by using low color temperature lights as street segment intersect these zones. Two major considerations in riparian zones are insect attraction and bat impacts, since both groups will be found at higher density in these zones. Best practices for reducing impacts to bats (Voigt et al. 2018) include a limit on light at the edge of habitat of 0.1 lux, avoiding direct glare into habitats, and seeking to avoid light <540 nm. A low CCT light would minimize insect attraction (Longcore et al. 2018a). Red lights are being used in Europe to minimize impacts to bats (Spoelstra et al. 2017) but it is not clear if red light would be acceptable within this context.

4.2.4 Community Parks and Natural Lands

Community parks and natural lands may contain sensitive species and often have areas that are closed after dark. Lighting surrounding them could be limited in CCT to 2200 K and lights on roads within parks might be shut off after a curfew. Darkness in these instances can serve to reduce unwanted activity because any lights brought into a dark park would indicate unallowable activity. Recommendations for community parks and natural lands will probably need to be tailored by site to accommodate variations in use, park type, and surrounding land uses. Tracy Aviary is located in a community park and has captive birds that are kept outdoors. Reducing or eliminating street lighting around any outdoor exclosures with captive birds is recommended for the health of the birds.

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SALT LAKE CITY, UT

Street Lighting Master Plan

VOLUME 2 - TECHNICAL GUIDANCE AND IMPLEMENTATION

CLANTON & ASSOCIATES
LIGHTING DESIGN AND ENGINEERING

GSBS CONSULTING

SALT LAKE CITY

JUNE 2020

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LIGHTING DESIGN PROCESS

HOW TO USE THIS DESIGN GUIDE

This section outlines the street lighting design process and the steps to developing quality street and pedestrian lighting. The criteria used is from the Illuminating Engineering Society of North America's (IES) American National Standard Practice for Roadway Lighting (RP-8-18).

Lighting designers should evaluate each lighting installation on a block by block basis and use the criteria to identify the appropriate lighting strategy based on the information provided in the following sections.

LUMINAIRE SUBMITTAL FORMS

Designers and engineers will use street and pedestrian luminaire submittal forms found in Appendix E to ensure that all luminaire criteria, set forth in this chapter as well as in the Luminaire Criteria Tables, are met. These forms should be completed during the lighting design process and most of the information on the forms can be found in the luminaire specification sheet. These forms will aid the City in approving luminaire selection for construction.

PROCESS FOR EVALUATING THE LIGHTED ENVIRONMENT

DETERMINE LIGHTING STRATEGY BASED ON SITE LOCATION

The majority of lighting installations in Salt Lake City are street and/or pedestrian lights for which the City has adopted a standard. Using the same equipment for most installations reduces inventory and makes replacements and repairs more efficient and cost effective. However, this master plan and existing lighting programs allow for areas within the city to differentiate themselves with unique lighting features. When designing street and pedestrian lighting, the designer must be aware of the area and if there are any unique influences. All new lighting in a character area should match and comply with luminaire style and criteria established in this Master Plan. Some character districts in the City, such as residential areas, may require lighting redesign, regardless of existing conditions to meet applicable criteria. Areas not included in a character district will be lighted with cobrahead style luminaires and standard pedestrian scale luminaires that meet the criteria and spacing based on road classification established in the Master Plan.

ESTABLISH LIGHTING WARRANTS

The Lighting Warrants Table below considers all factors and leads the designer to the appropriate lighting strategy based on street classification, adjacent land use, and pedestrian conflict. The next sections provide the user with background and guidance on the Lighting Warrants Chart to identify appropriate attributes and select the appropriate lighting strategy. The designer must use the appropriate strategy and include any character influences in their design. Not all streets in the City will warrant continuous lighting, but all streets with continuous lighting must meet the lighting criteria set forth by IES RP-8-18.

TABLE 1: LIGHTING WARRANTS - ARTERIAL

ARTERIAL STREET						
	PED	EXISTING CONDITIONS	STREET LIGHTING		PED LIGHTING	PG. #
COMMERCIAL	HIGH	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont	25, 31
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous	29
	MED	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.	25
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.	31
	LOW	Sidewalk Lit By Streetlight	Non-Cont		NA	27
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA	27
OFFICE PARK	LOW	Sidewalk Lit By Streetlight	Non-Cont.		NA	27
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA	27
DOWNTOWN	HIGH	Cactus Poles	Continuous Cactus Pole Lighting			19
		Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.	25, 31
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous	29
	MED	Cactus Poles	Continuous Cactus Pole Lighting			19
		Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.	25
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.	31
INDUSTRIAL	LOW	Sidewalk Lit By Streetlight	Int. Only		NA	33
		Sidewalk NOT Lit by Streetlight	Int. Only		NA	33
MULTIFAMILY RESIDENTIAL	MED	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.	25, 31
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.	31
SINGLE FAMILY RESIDENTIAL	LOW	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.	25, 31
		Sidewalk NOT Lit by Streetlight	Continuous	Optional	Non-cont.	25, 31
OPEN SPACE	MED	Sidewalk Lit By Streetlight	Non-Cont.		NA	27
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA	27
	LOW	Sidewalk Lit By Streetlight	Int. Only		NA	33
		Sidewalk NOT Lit by Streetlight	Int. Only		NA	33

* High pedestrian conflict is only found in Downtown, Sugarhouse, Trolley Square, and within one block of the University of Utah and Smith's Ballpark

TABLE 2: LIGHTING WARRANTS - COLLECTOR

COLLECTOR						
	PED	EXISTING CONDITIONS	STREET LIGHTING		PED LIGHTING	PG. #
COMMERCIAL	HIGH	Sidewalk Lit By Streetlight	Continuous	OR	Continuous	34
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous	38
	MED	Sidewalk Lit By Streetlight	Continuous	OR	Continuous	34
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.	40
	LOW	Sidewalk Lit By Streetlight	Non-cont.		NA	36
		Sidewalk NOT Lit by Streetlight	Non-Cont.		NA	36
OFFICE PARK	LOW	Sidewalk Lit By Streetlight	Non-cont.		NA	36
		Sidewalk NOT Lit by Streetlight	Non-cont.		NA	36
DOWNTOWN	HIGH	Cactus Poles	Continuous Cactus Pole Lighting			19
		Sidewalk Lit By Streetlight	Continuous	OR	Continuous	34
		Sidewalk NOT Lit by Streetlight	Continuous	&	Continuous	38
	MED	Cactus Poles	Continuous Cactus Pole Lighting			19
		Sidewalk Lit By Streetlight	Continuous	OR	Continuous	34
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-Cont.	40
INDUSTRIAL	LOW	Sidewalk Lit By Streetlight	Int. Only		NA	44
		Sidewalk NOT Lit by Streetlight	Int. Only		NA	44
MULTIFAMILY RESIDENTIAL	MED	Sidewalk Lit By Streetlight	Continuous	Optional	Non-cont.	42
		Sidewalk NOT Lit by Streetlight	Continuous	&	Non-cont.	40
SINGLE FAMILY RESIDENTIAL	LOW	Sidewalk Lit By Streetlight	Non-Cont.	OR	Non-cont.	36,42
		Sidewalk NOT Lit by Streetlight	Int. Only	&	Non-cont.	44,42
OPEN SPACE	MED	N/A				
	LOW	Sidewalk Lit By Streetlight	Int. Only		NA	44
		Sidewalk NOT Lit by Streetlight	Int. Only		NA	44

* High pedestrian conflict is only found in Downtown, Sugarhouse, Trolley Square, and within one block of the University of Utah and Smith's Ballpark

TABLE 3: LIGHTING WARRANTS - LOCAL

LOCAL						
	PED	EXISTING CONDITIONS	STREET LIGHTING		PED LIGHTING	PG. #
COMMERCIAL	HIGH	Sidewalk Lit By Streetlight	Continuous	OR	Continuous	45,50
		Sidewalk NOT Lit by Streetlight	Non-cont.	&	Continuous	48
	MED	Sidewalk Lit By Streetlight	Non-Cont.	OR	Continuous	47, 50
		Sidewalk NOT Lit by Streetlight	Non-cont.	OR	Continuous	47, 50
	LOW	Sidewalk Lit By Streetlight	Int. Only	OR	Non-cont.	36
		Sidewalk NOT Lit by Streetlight	Int. Only	OR	Non-cont.	36
OFFICE PARK	LOW	Sidewalk Lit By Streetlight	Int. Only	OR	Non-cont.	53, 52
		Sidewalk NOT Lit by Streetlight	Int. Only	OR	Non-cont.	53, 52
DOWNTOWN	HIGH	Cactus Poles	Continuous Cactus Pole Lighting			19
		Sidewalk Lit By Streetlight	Continuous	OR	Continuous	45,50
		Sidewalk NOT Lit by Streetlight	Non-cont.	&	Continuous	48
	MED	Cactus Poles	Continuous Cactus Pole Lighting			19
		Sidewalk Lit By Streetlight	Non-Cont.	OR	Continuous	47, 50
		Sidewalk NOT Lit by Streetlight	Non-Cont.	OR	Continuous	47, 50
INDUSTRIAL	LOW	Sidewalk Lit By Streetlight	Int. Only		NA	53
		Sidewalk NOT Lit by Streetlight	Int. Only		NA	53
MULTIFAMILY RESIDENTIAL	MED	Sidewalk Lit By Streetlight	Int. Only	&	Continuous	53
		Sidewalk NOT Lit by Streetlight	Int. Only	&	Continuous	53
SINGLE FAMILY RESIDENTIAL	LOW	Sidewalk Lit By Streetlight	Int. Only	Optional	Non-Cont.	53, 52
		Sidewalk NOT Lit by Streetlight	Int. Only	Optional	Non-cont.	53, 52
OPEN SPACE	MED	N/A				
	LOW	Sidewalk Lit By Streetlight	Int. Only		NA	53
		Sidewalk NOT Lit by Streetlight	Int. Only		NA	53

* High pedestrian conflict is only found in Downtown, Sugarhouse, Trolley Square, and within one block of the University of Utah and Smith's Ballpark

DETERMINE STREET CLASSIFICATIONS

Street classification is used to determine the lighting warrants for a street, along with the surrounding environment and pedestrian conflict. Figure 1 shows all street classifications throughout the city. The following street and roadway definitions are from IES RP-8-18.

FREEWAY:

A divided highway with full control of access. Oftentimes with great visual complexity and high traffic volumes. This roadway is usually found in major metropolitan areas in or near the central core and will operate at or near design capacity through some of the early morning or late evening hours of darkness.

*Freeway, which are UDOT facilities, are not included in the scope of this Masterplan.

MAJOR (ARTERIAL):

That part of the roadway system that serves as the principle network for through-traffic flow. The routes connect areas of principle traffic generation and important rural roadways entering and leaving the city. These routes are often known as "arterials". They are sometimes subdivided into primary and secondary; however, such distinctions are not necessary in roadway lighting. These routes primarily serve through traffic and secondarily provide access to abutting property.

COLLECTOR:

Roadways servicing traffic between major and local streets. These are streets used mainly for traffic movements within residential, commercial, and industrial areas. They do not handle long, through trips. Collector streets may be used for truck or bus movements and give direct service for abutting properties.

LOCAL:

Local streets are used primarily for direct access to residential, commercial, industrial, or other abutting property. They make up a sizable percentage of the total street system but carry a small proportion of vehicular traffic.

INTERSECTIONS:

A traffic conflict area in which two or more streets join or cross at the same grade. The outside edge of pedestrian crosswalks defines intersection limits. If there are no pedestrian crosswalks, the stop bars define the intersection. If there are no stop bars, the intersection is defined by the radius return of each intersection leg. Intersection limits may also include the area encompassing channelized areas in which traffic is directed into definite paths by islands with raised curbing.

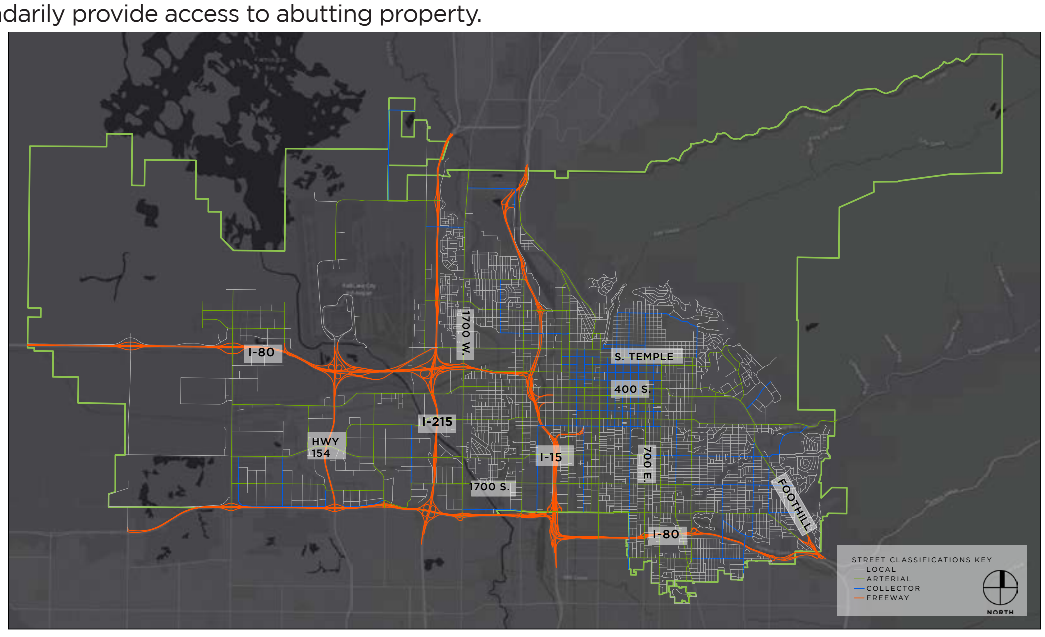

Figure 1: Street Classifications Map

DETERMINE ADJACENT LAND USE

Adjacent land use is a key factor in determining lighting strategy as it directly correlates to the number of pedestrians and vehicles in the area during nighttime hours. Areas of increased traffic volume at night warrant additional lighting, whereas areas that typically do not have much traffic after dark warrant base level lighting. Figure 2 is the Land Use Map. Adjacent land use should be evaluated according to the consolidated zoning provided in this master plan. For projects that are on the boundaries between land uses, the designer should select the lower criteria with more stringent light trespass to protect residential and open space uses. If the project includes areas that are within, or adjacent to, a Critical Wildlife Area, all luminaire installed should meet the luminaire requirements of the protected area.

COMMERCIAL

Commercial land use is a diverse classification encompassing high, medium and low pedestrian and traffic volumes. Areas with concentrated restaurant and retail establishments, such as the Sugarhouse Business District and 9th & 9th, typically see medium to high pedestrian and traffic volumes during nighttime hours and should have increased light levels and possibly additional pedestrian lighting. However, big box stores and strip malls do not typically see the same number of pedestrians during nighttime hours and can have reduced light levels. Designers must carefully evaluate the pedestrian and traffic volume where lighting improvements are being made and select the proper lighting criteria to create a safe and comfortable nighttime environment for pedestrians and vehicles.

OFFICE PARK

Office Parks are defined as areas where people tend to work during the day but are mostly vacant during nighttime hours. Establishments in this classification are generally open between 8:00 A.M. and 6:00 P.M. but typically close in the early evening and are not open into the night.

DOWNTOWN

Downtown Salt Lake City is the heart of the retail and restaurant business in the valley and attracts people at all times of the day. This area typically sees high and medium pedestrian and traffic volumes and is lighted by the historic Cactus Poles. Lighting in Downtown should focus on pedestrian safety and properly illuminating crosswalks and sidewalks. In most cases luminaire spacing has already been established so it is essential that designers select the proper distribution and lumen output

INDUSTRIAL

Industrial land use is defined by manufacturing and distribution within the City. This land use includes, but is not limited to, the establishments found south of the airport off of California Ave. Industrial land use has very minimal pedestrian usage, especially during nighttime hours and requires minimal lighting. Additionally, most of the industrial land use areas within Salt Lake City are also within Critical Wildlife Habitats and will require appropriate lighting to minimize environmental impacts.

MULTIFAMILY RESIDENTIAL

Multifamily residential is characterized by multiple separate housing units for residential inhabitants are contained within on building or several buildings within one complex. When designing lighting on streets adjacent to multifamily residential areas a medium pedestrian conflict should be used as there are typically higher pedestrian and vehicle volumes. Residential areas are typically on streets with lower speed limits and less traffic, however this is not always the case. Salt Lake City has residential land use on all street classifications, arterial, collector and local creating multiple lighting strategies that may be appropriate. Designers should consider the safety of pedestrian and vehicles when selecting the appropriate lighting strategy while respecting the residents by minimizing light trespass.

SINGLE FAMILY RESIDENTIAL

Single family residential is characterized by a stand-alone dwelling serving as the primary residence for one family. Single family residential areas typically have less pedestrian volume, and when designing lighting in these areas, a low pedestrian conflict should be used. Residential areas are typically on streets with lower speed limits and less traffic, however this is not always the case. Salt Lake City has residential land use on all street classifications, arterial, collector and local, creating multiple lighting strategies that may be appropriate. Designers should consider the safety of pedestrian and vehicles when selecting the appropriate lighting strategy while respecting the residents by minimizing light trespass.

OPEN SPACE

The purpose of the OS Open Space District is to preserve and enhance public and private open space, natural areas, and improved park and recreational areas. These areas provide opportunities for active and passive outdoor recreation, provide contrasts to the built environment, preserve scenic qualities, and protect sensitive or fragile environmental areas. Examples of Open Space within the City include City Creek Canyon, Salt Lake City Cemetery, and along the Jordan River. Any Streets bordering the foothills are considered to be along Open Space as well. These streets typically see minimal pedestrian usage and are within Critical Habitat areas requiring additional measures to ensure environmentally friendly street lights are used.

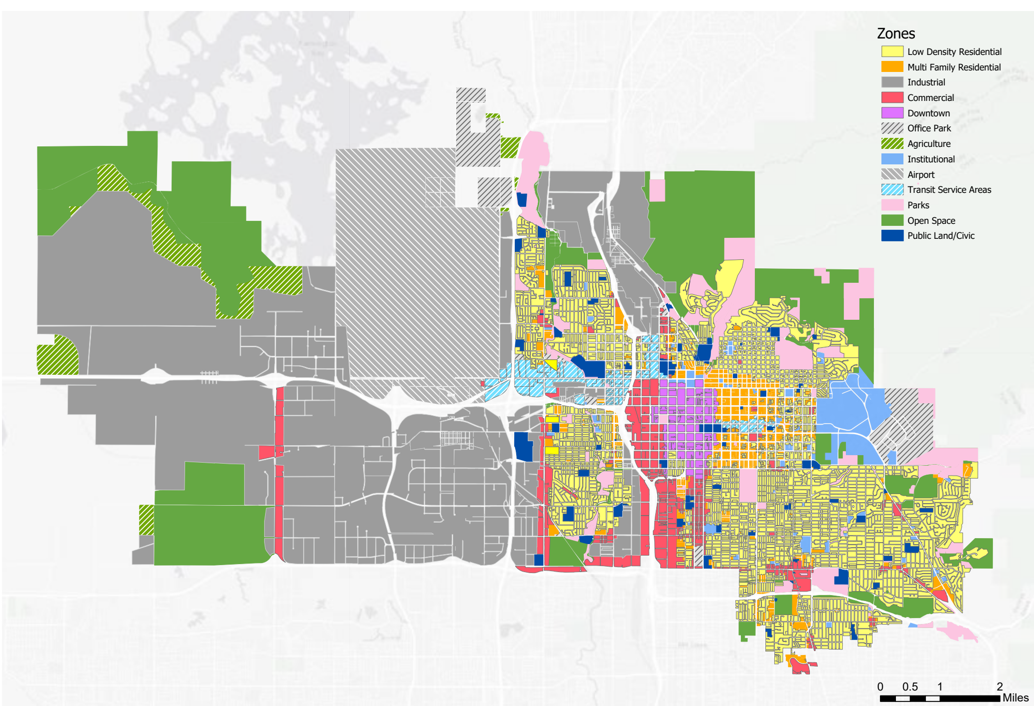

Figure 2: Adjacent Land Use Map

DETERMINING PEDESTRIAN ACTIVITY LEVELS

IES pedestrian volumes represent the total number of pedestrians walking in both directions on a typical block or 660 foot section. Pedestrian counts and traffic studies take precedence over other references. The following are pedestrian classification definitions per IES RP-8-18. The pedestrian counts should be taken during darkness hours when the typical peak number of pedestrians are present. This typically occurs during early morning hours if a school or similar destinations are nearby. The lighting designer should determine what the typical peak hours are for each street.

HIGH:

Areas with significant numbers (over 100 pedestrians an hour) of pedestrians expected to be on the sidewalks or crossing the streets during darkness. Examples are downtown retail areas, near theaters, concert halls, stadiums, and transit terminals.

MEDIUM:

Areas where fewer (10 to 100 pedestrians an hour) pedestrians utilize the streets at night. Typical are downtown office areas, blocks with libraries, apartments, neighborhood shopping, industrial, parks, and streets with transit lines.

LOW:

Areas with very low volumes (10 or fewer pedestrians per hour) of night pedestrian usage. A low pedestrian classification can occur in any street classifications but may be typified by suburban streets with single-family dwellings, very low-density residential developments, and rural or semi-rural areas.

COMPREHENSIVE IMPROVEMENTS

PURPOSE

This section applies to new installations of public street and pedestrian lighting, either standalone or on traffic signal installations, and modifications to existing street lighting installations that affect pole types or locations, excluding minor maintenance work. Refer to Volume 2: Minimal Improvements for projects involving 1-for-1 luminaire replacement and supplemental improvements.

LIGHTING DESIGN PROCESS

Performing a lighting design for new installations of streetlights is an iterative process. This occurs because the lighting design is altered (spacing, arrangement, mounting height) until the target goal is met, per criteria set forth in this document, for the specific street. The most efficient method is to calculate luminance for straight streets or illuminance for intersections and non-straight streets, along with sidewalks and other pedestrian areas with varying luminaire parameters. The selected luminaire must comply with the lumen output, efficacy, BUG ratings, and other luminaire requirements specified in Volume 2. Care should be taken, when selecting a luminaire to illuminate the surrounding sidewalks and public spaces without causing light trespass, or unwanted light spills onto surrounding properties and through residential windows. Instructions on setting up the lighting design calculations are found later in this volume.

Lighting designers should use the Lighting Warrants Table to determine the appropriate strategy based on street classification, adjacent land use, and pedestrian conflict. Once the appropriate lighting strategy is determined, designers can find lighting and luminaire criteria and spacing guidance in the corresponding sheets below. All lighting layouts for each street classification are broken out below and should be referenced during the design process.

LIGHTING APPLICATIONS

The following pages describe the luminaire selection and lighting layout for each street classification as defined by the Salt Lake City Transportation Division. Designers should strive to meet the luminaire spacing that will provide the highest quality street lighting possible, but this is not always feasible. It is necessary to integrate lighting locations in correspondence to other improvements:

- Clearance from driveways (10 feet commercial and 5 feet residential).
- Clearance from fire hydrants (5 feet).
- Trees (centered in between trees or 20 feet from the tree trunk).
- Streetlight offset should be a minimum of 3'-0" and a maximum of 8'-0" from back of curb.
- Pedestrian lights should be a minimum of 1'-0" and a maximum of 6'-0" from the sidewalk.
- Light standards integrated into sidewalk should maintain a minimum of 5'-0" clear zone.
- Light standards should be located a minimum distance of 10'-0" from trees.

Place poles and luminaires near property lines wherever practical and avoid locations in front of doorways, windows, and lines of egress.

INTERSECTIONS & CROSSWALKS

The same luminaires are to be used throughout the intersection. When an intersection is between two different street classifications, the higher street classification target criteria is used throughout the entire intersection. The recommended streetlight layout for an intersection also depends on whether the street classification calls for continuous or non-continuous lighting.

The following requirements are recommended to guide all traffic signal mounted streetlights. The intersection design should ensure that the crosswalks are sufficiently lighted to light the vertical surface (body) of pedestrians in the crosswalk. This may require that additional streetlights be located before the intersection as shown in the Figures 3 and 4 below.

Mid-block crossings and denoted crosswalks are recommended to always be lighted. Crosswalks can be denoted by striping, signage, flashing beacons, etc. Crosswalks are important parts of the streetscape and an appropriate lighting design will improve the visibility of pedestrians in the crosswalk. The lighting should be installed between the vehicle and the crosswalk (ie: half to one pole height before the crosswalk) to ensure that the body of the pedestrian is adequately lighted. If streetlights are installed above or immediately adjacent to the crosswalk, only the top of the pedestrian's head will be lighted making it difficult for motorists to see the pedestrian. Crosswalks and mid-block crossings are recommended to be lighted to the Vertical Illuminance requirements in the table below. Vertical illuminance measurements are taken 5ft. above the roadway surface in the direction of oncoming traffic.

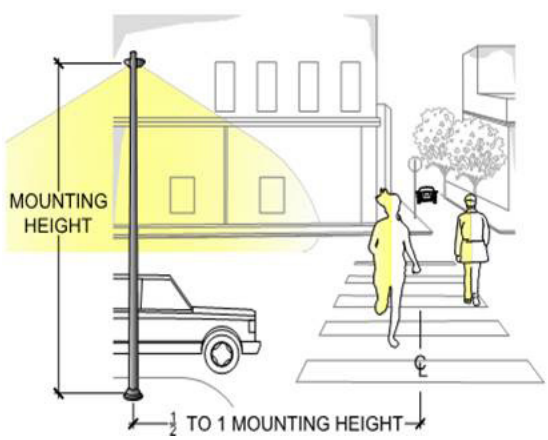

Figure 3: Streetlight Located Before Crosswalk

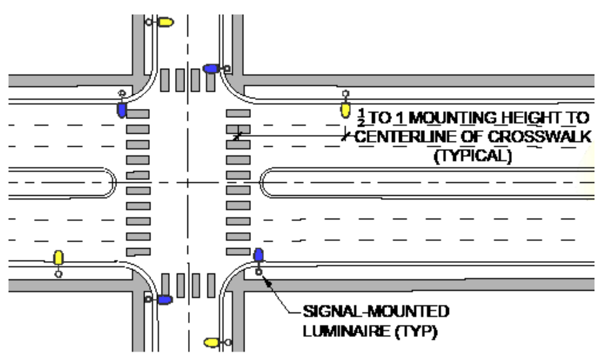

Figure 4: Streetlight Placement with Respect to Crosswalk

TABLE 4: INTERSECTION & CROSSWALK TARGET HORIZONTAL CRITERIA PER IES RP-8-18

STREET CLASS	PED CONFLICT	AVERAGE HORIZONTAL ILLUMINANCE (FC)	UNIFORMITY RATIO (FCAVG/ FCMIN)	AVERAGE VERTICAL ILLUMINANCE (FC)	MOUNTING HEIGHT (FEET)	MAST ARM LENGTH (FT)	DISTRIBUTION	MAX BUG RATING	LUMEN OUTPUT RANGE
Arterial / Arterial	High	3.4	3	1.4	35-40	10	Type 2 or 3	3-0-3	16,000-25,000
	Medium	2.6	3	0.9	35-40	10	Type 2 or 3	3-0-3	10,000-16,000
	Low	1.8	3	0.5	30-40	10	Type 2 or 3	2-0-2	7,000-12,000
Arterial / Collector	High	2.9	3	0.9	35-40	10	Type 2 or 3	3-0-3	10,000-18,000
	Medium	2.2	3	0.6	35-40	10	Type 2 or 3	2-0-2	8,500-13,500
	Low	1.5	3	0.4	30-40	10	Type 2 or 3	2-0-2	5,000-10,000
Arterial / Local	High	2.6	3	0.8	30-35	10	Type 2 or 3	3-0-3	10,000-16,000
	Medium	2.0	3	0.6	30-35	10	Type 2 or 3	2-0-2	7,500-12,500
	Low	1.3	3	0.4	30-35	10	Type 2 or 3	2-0-2	4,000-8,500
Collector / Collector	High	2.4	4	0.7	30-35	6	Type 2 or 3	2-0-2	7,500-12,000
	Medium	1.8	4	0.5	30-35	6	Type 2 or 3	2-0-2	4,500-7,500
	Low	1.2	4	0.5	30-35	6	Type 2 or 3	1-0-2	3,500-6,000
Collector / Local	High	2.1	4	0.6	30-35	6	Type 2 or 3	2-0-2	6,000-10,500
	Medium	1.6	4	0.5	30-35	6	Type 2 or 3	1-0-2	4,000-7,000
	Low	1.0	4	0.3	30-35	6	Type 2 or 3	1-0-2	3,000-5,500
Local / Local >30mph	High	1.8	6	0.5	25-30	6	Type 2 or 3	2-0-2	5,000-8,000
	Medium	1.4	6	0.4	25-30	6	Type 2 or 3	1-0-1	4,000-6,000
	Low	1.0	6	0.2	25-30	6	Type 2 or 3	1-0-1	3,000-5,500
Local / Local <30mph	High	N/A							
	Medium	N/A							
	Low	N/A							

* A U2 BUG rating is acceptable when using a house side shield?
1. Arterial mid block crossing shall follow the arterial/arterial intersection criteria.
2. Collector mid block crossing shall follow the collector/collector intersection criteria.

SIGNALIZED/CONTINUOUS LIGHTING

For a signalized intersection with continuous lighting the typical streetlight arrangement is interrupted by placing streetlight signal poles. This is called out as “1/2 to 1 mounting height to centerline of crosswalk (Typical)” in Figure 5 below. Additional streetlights should be located on signal poles if additional lighting is needed to meet the intersection criteria.

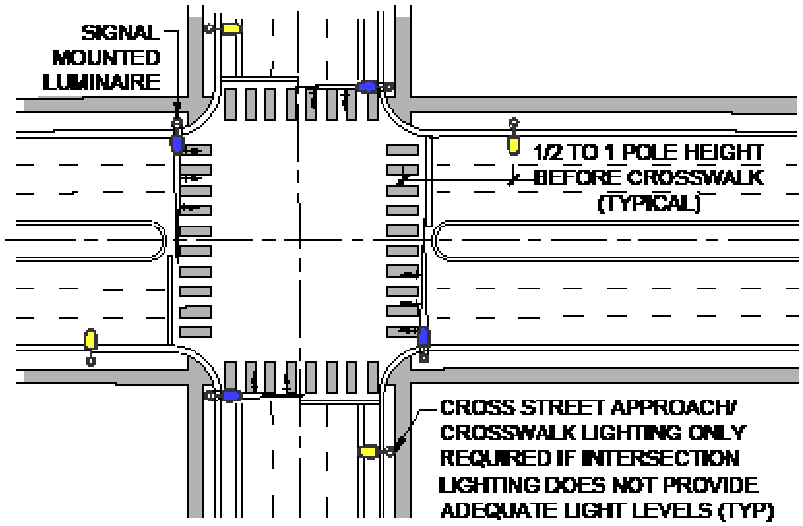

Figure 5: Typical Intersection Lighting Layout with Signals and Continuous Lighting

NON- SIGNALIZED/CONTINUOUS LIGHTING

For a non-signalized intersection with continuous lighting the typical streetlight arrangement is continued through the intersection (see Figure 6). The streetlights should be located along the approach to the crosswalk, if it exists, installed half to one luminaire mounting height in front of the crosswalk, between approaching vehicles and pedestrians.

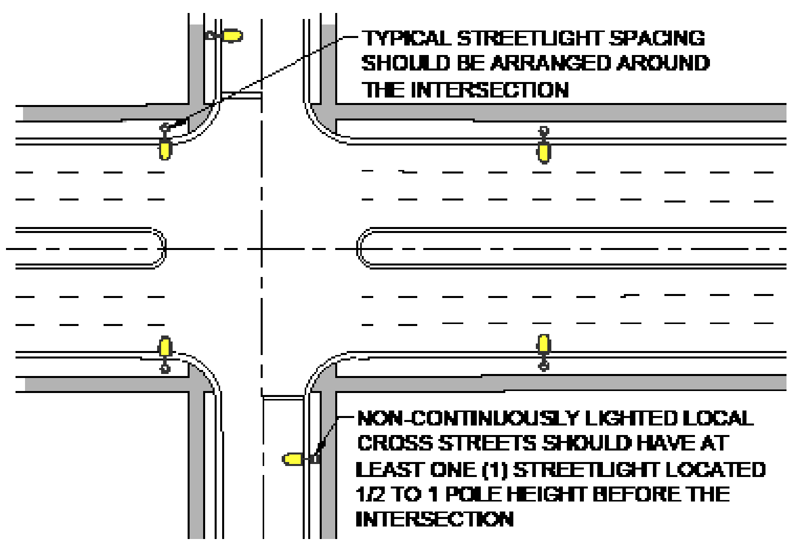

Figure 6: Typical Intersection Lighting Layout with No Signals and Continuous Lighting

SIGNALIZED/NON-CONTINUOUS LIGHTING

For signalized intersections with non-continuous lighting luminaires are located half to one luminaire mounting height in front of the crosswalk, illuminating the approach to the intersection. If these four luminaires do not provide sufficient lighting throughout the entire intersection, two more additional luminaires may be used, to be mounted on the signals as shown in Figure 7.

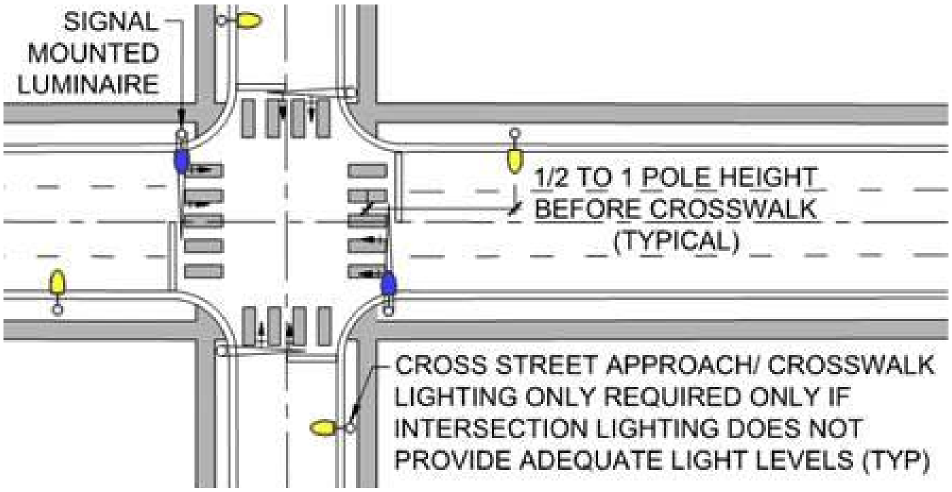

Figure 7: Typical Intersection Lighting Layout with Signals and Non-Continuous Lighting

NON-SIGNALIZED/NON-CONTINUOUS LIGHTING

For streets with non-continuous lighting and no signals, one luminaire is to be placed at each intersection, as shown in Figure 8. Refer to the Local Street chapter for more information.

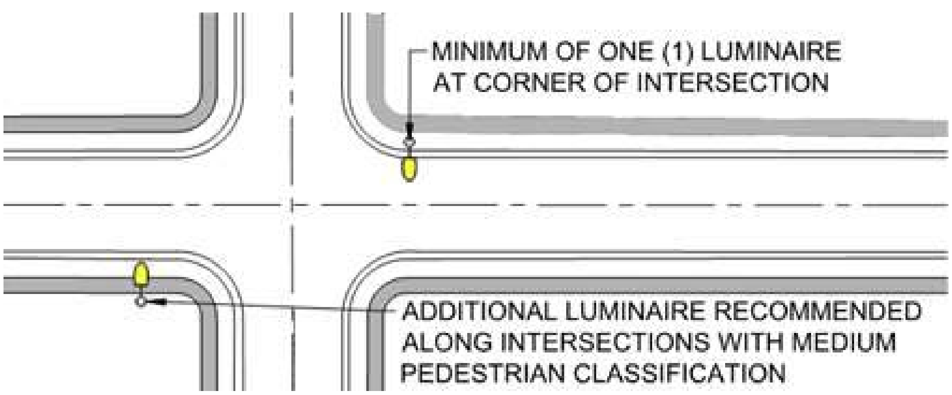

Figure 8: Typical Intersection Lighting Layout with No Signals and Non-Continuous Lighting

MID-BLOCK CROSSWALKS

The standard is a streetlight located one half to 1 mounting height in front of the crosswalk on both sides of the street for all mid-block crossings, shown in Figures 9 and 10.

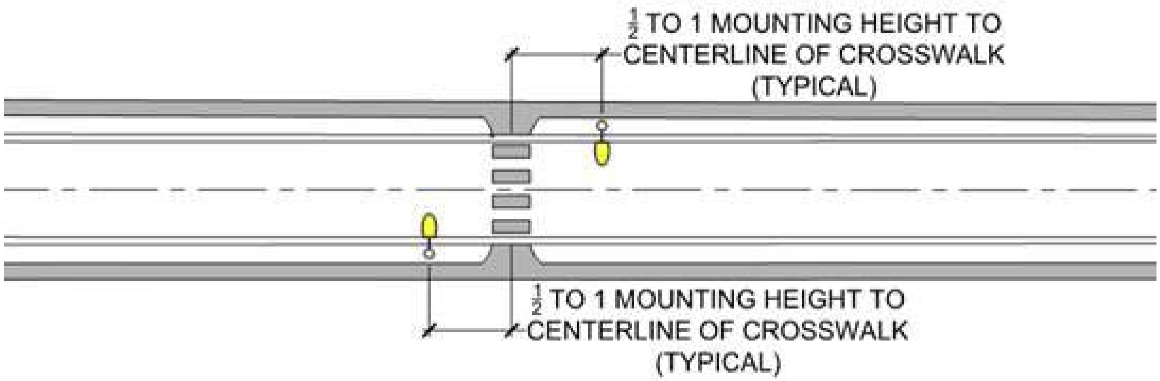

Figure 9: Streetlight Placement with Respect to Mid-Block Crossing

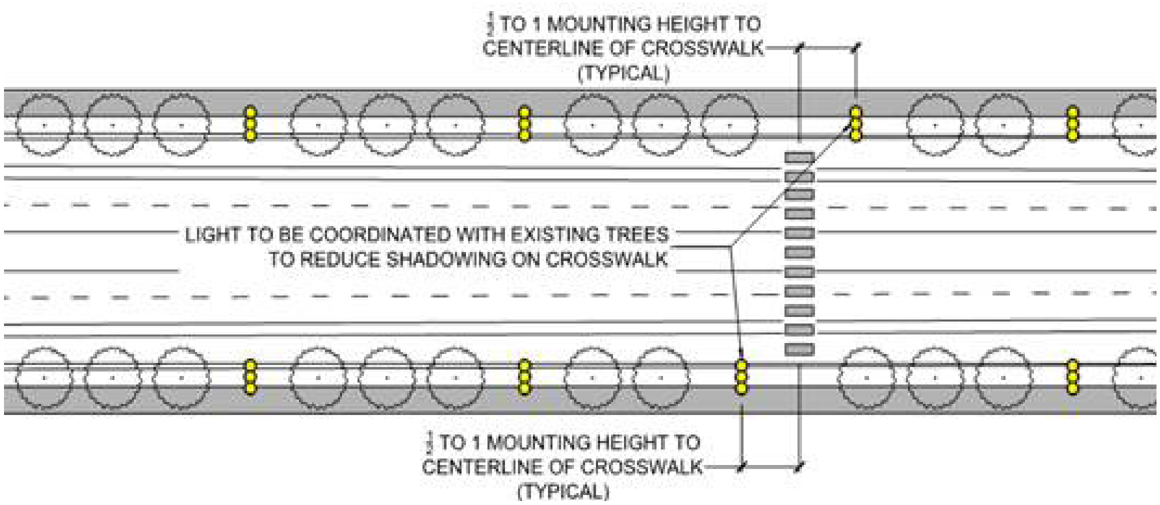

Figure 10: Cactus Pole Placement with Respect to Mid-Block Crossing

CACTUS POLE LAYOUTS

Cactus Poles within downtown SLC should be upgraded to fully shielded LED luminaires. The Cactus Pole locations and spacing will not change, but the lumen output and distribution of new luminaire should meet the criteria in Table 7 and 8 based on the location of the lighting improvements seen in Figure 11 and 12.

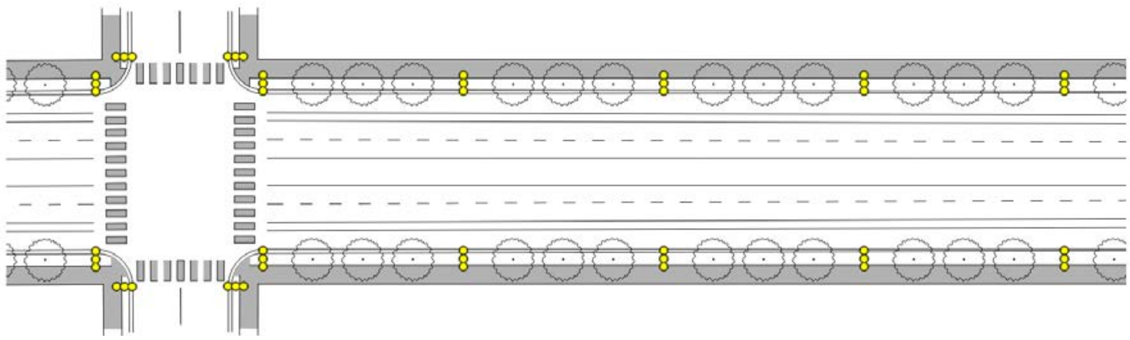

Figure 11: Cactus Pole Lighting Layouts

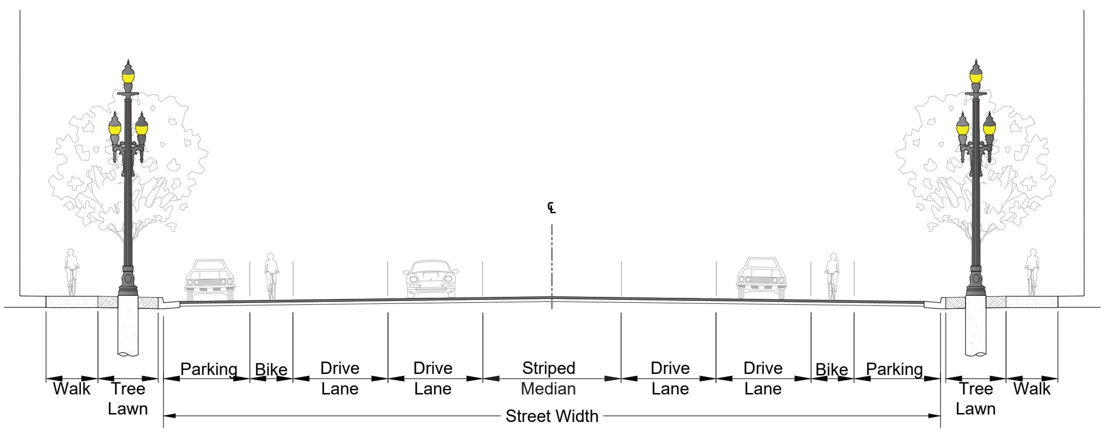

Figure 12: Cactus Pole Sections

TABLE 5: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	1.2	3:1	1.0
Medium	0.9	3:1	0.5

TABLE 6: COLLECTOR STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	0.8	3:1	1.0
Medium	0.6	4:1	0.5

TABLE 7: RECOMMENDED CACTUS POLE LUMINAIRE CRITERIA - ARTERIAL STREETS

STREET WIDTH	PEDESTRIAN ACTIVITY	STREET LIGHT LUMEN OUTPUT (LM)	STREET LIGHT PHOTOMETRIC DISTRIBUTION	MAX. STREET LIGHT BUG RATING	PEDESTRIAN LIGHT LUMEN OUTPUT (LM)	PEDESTRIAN LIGHT PHOTOMETRIC DISTRIBUTION	MAX. PEDESTRIAN LIGHT BUG RATING
70-90	High	8,500-10,500	Type III or IV	B3-U0-G2*	3,000-5,000	Type III or IV	B1-U0-G1
	Medium	5,500-9,000	Type III	B3-U0-G2*	3,000-5,000	Type III	B1-U0-G1
90-110	High	6,500-9,500	Type II	B3-U0-G2*	3,500-5,500	Type III	B1-U0-G1
	Medium	8,000-11,500	Type III	B3-U0-G2*	2,500-5,000	Type II or III	B1-U0-G1

** These BUG Ratings apply to all Cactus Pole lights, except at intersections and mid-block pedestrian crossings, which may have B3-U3-G2 Ratings to provide adequate vertical illuminance at crosswalks."*

TABLE 8: RECOMMENDED CACTUS POLE LUMINAIRE CRITERIA - COLLECTOR STREETS

STREET WIDTH	PEDESTRIAN ACTIVITY	STREET LIGHT LUMEN OUTPUT (LM)	STREET LIGHT PHOTOMETRIC DISTRIBUTION	MAX. STREET LIGHT BUG RATING	PEDESTRIAN LIGHT LUMEN OUTPUT (LM)	PEDESTRIAN LIGHT PHOTOMETRIC DISTRIBUTION	MAX. PEDESTRIAN LIGHT BUG RATING
70-90	High	5,500-8,500	Type III or IV	B2-U0-G2	2,500-4,500	Type III or IV	B1-U0-G1
	Medium	4,500-8,000	Type II or IV	B2-U0-G2	2,500-4,500	Type III or IV	B1-U0-G1
90-110	High	9,000-11,500	Type III	B3-U0-G2	3,000-5,000	Type III or IV	B1-U0-G1
	Medium	4,500-7,500	Type III or IV	B2-U0-G2	3,000-5,000	Type III or IV	B1-U0-G1

SUGARHOUSE POLE LAYOUT

The teardrop luminaires in the Sugarhouse Business District should be upgraded to fully shielded LED luminaires. The locations and spacing will not change, but the lumen output and distribution of new luminaire should meet the criteria in Table 10. This is illustrated in Figures 13 and 14.

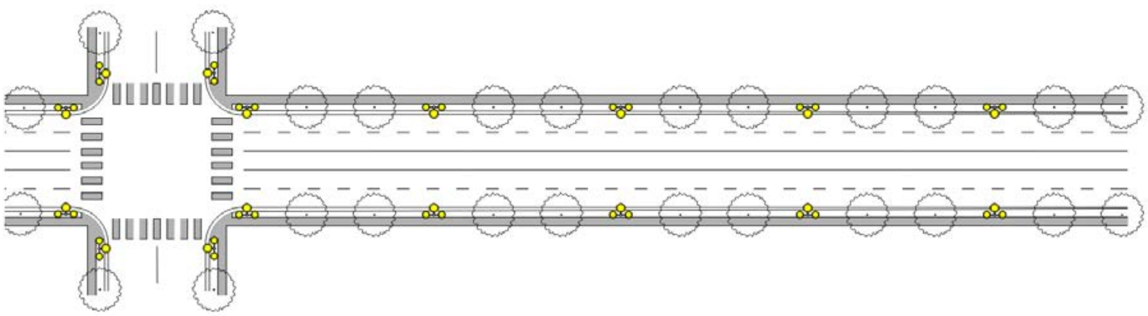

Figure 13: Sugarhouse Pole Lighting Layouts

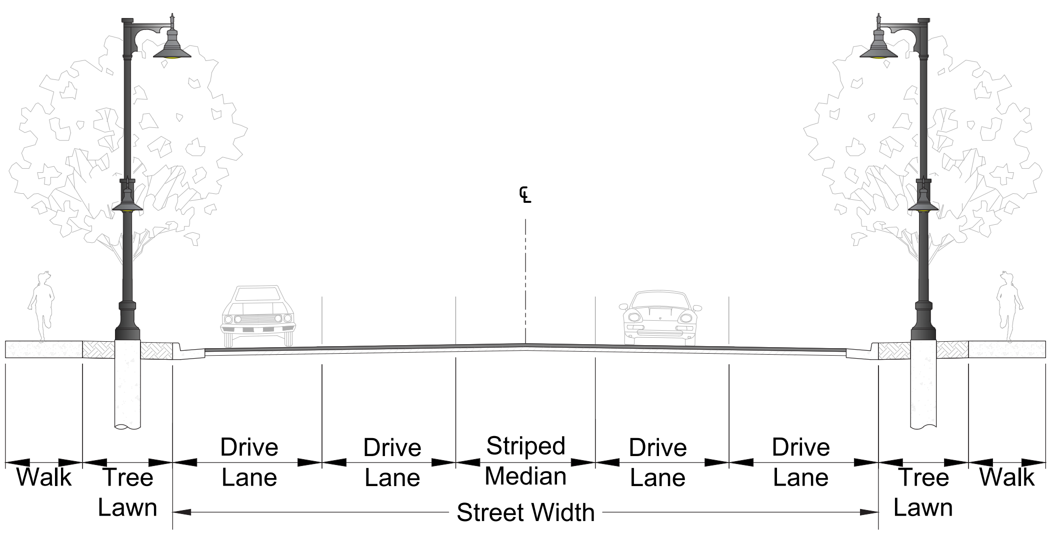

Figure 14: Sugarhouse Pole Lighting Section

TABLE 9: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	1.2	3:1	1.0
Medium	0.9	3:1	0.5

TABLE 10: RECOMMENDED SUGARHOUSE POLE LUMINAIRE CRITERIA

PEDESTRIAN ACTIVITY	STREET LIGHT LUMEN OUTPUT (LM)	STREET LIGHT PHOTOMETRIC DISTRIBUTION	MAX. STREET LIGHT BUG RATING	PEDESTRIAN LIGHT LUMEN OUTPUT (LM)	PEDESTRIAN LIGHT PHOTOMETRIC DISTRIBUTION	MAX. PEDESTRIAN LIGHT BUG RATING
High	6,000-8,000	Type II or III	B2-U0-G2	2,000-3,000	Type II or III	B1-U0-G1
Medium	3,000-7,000	Type II or III	B2-U0-G1	1,000-2,000	Type II or III	B1-U0-G1

TEAR DROP POLE LAYOUT

The teardrop luminaires along South Temple and State Street should be upgraded to fully shielded LED luminaires. The locations and spacing will not change, but the lumen output and distribution of new luminaire should meet the criteria in Table 12. This is illustrated in Figures 15 and 16.

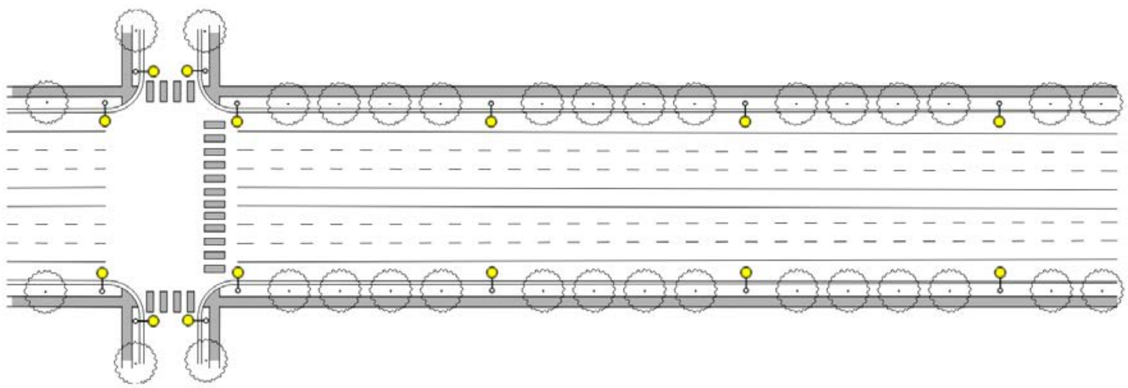

Figure 15: Tear Drop Lighting Layouts

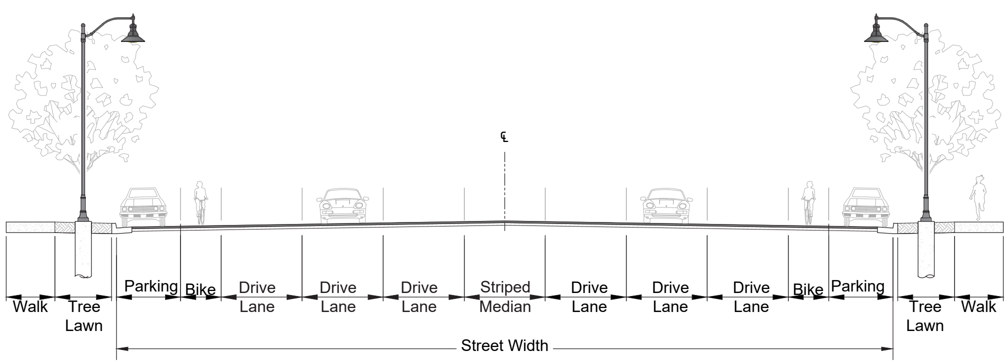

Figure 16: Tear Drop Lighting Section

TABLE 11: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	1.2	3:1	1.0
Medium	0.9	3:1	0.5
Low	0.6	4:1	0.4

TABLE 12: RECOMMENDED TEAR DROP LUMINAIRE CRITERIA

STREET WIDTH	PEDESTRIAN ACTIVITY	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
50-70	High	11,000-14,750	Type III	B2-U0-G2
	Medium	8,500-12,000	Type III	B2-U0-G2
	Low	5,500-8,500	Type III	B2-U0-G2
70-100	High	16,500-20,500	Type III	B3-U0-G3
	Medium	16,500-20,500	Type III	B3-U0-G3
	Low	11,000-16,500	Type III	B2-U0-G2

ARTERIAL STREET - CONTINUOUS STREET LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing an arterial street with only street lighting. Luminaires are to be placed in an opposite arrangement when not located at an intersection, Figures 17 and 18.

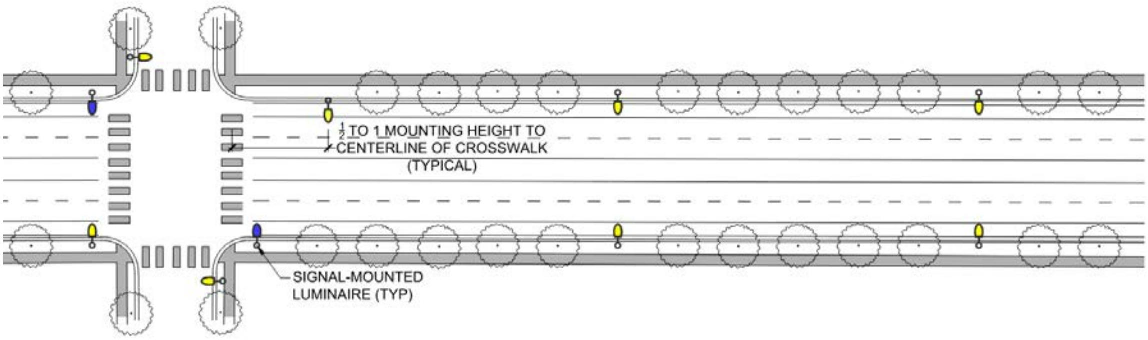

Figure 17: Typical Arterial with Continuous Street Lighting Plan

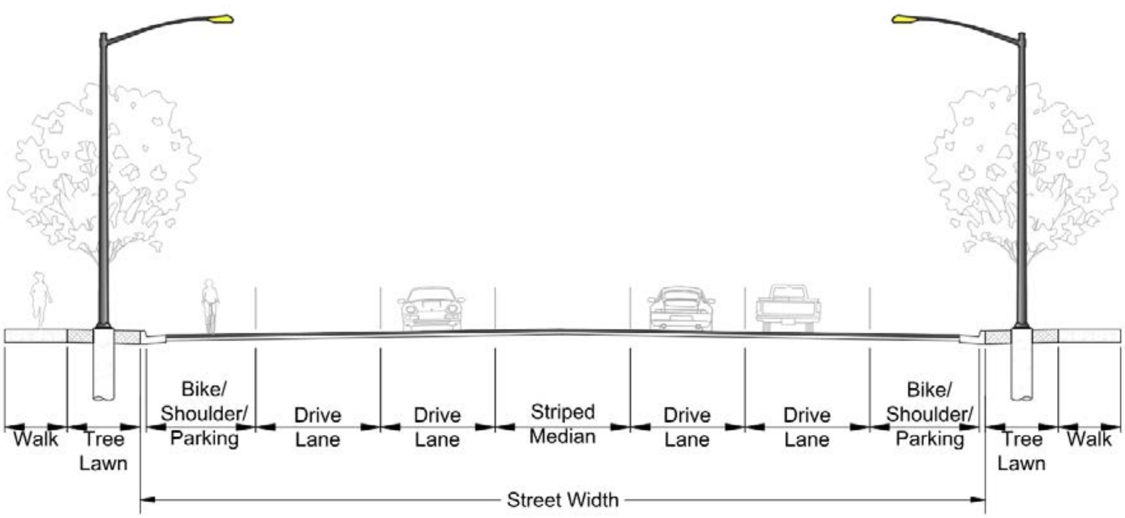

Figure 18: Typical Arterial with Continuous Street Lighting Cross Section

TABLE 13: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	1.2	3:1	1.0
Medium	0.9	3:1	0.5
Low	0.6	4:1	0.4

TABLE 14: RECOMMENDED ARTERIAL (NON-MEDIAN MOUNTED) LUMINAIRE & POLE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
50-70	High	120-140	30-35	6,500-9,000	Type II or III	B2-U0-G2
		140-180	30-35	8,500-14,000	Type II or III	B3-U0-G2
	Medium	140-180	30-35	6,500-9,000	Type II or III	B2-U0-G2
		180-220	30-35	8,500-10,000	Type II or III	B2-U0-G2
	Low	180-220	30-35	6,000-8,500	Type II or III	B2-U0-G2
70-90	High	140-180	30-35	8,500-12,000	Type II or III	B2-U0-G2
		180-220	30-35	12,000-18,000	Type II or III	B3-U0-G3
	Medium	120-160	30-35	7,500-10,000	Type II or III	B2-U0-G2
		160-200	30-35	8,500-12,000	Type II or III	B3-U0-G2
	Low	140-180	30-35	6,500-9,500	Type II or III	B2-U0-G2
		180-220	30-35	7,500-11,000	Type II or III	B2-U0-G2
90-110	High	120-160	30-35	11,000-18,000	Type II	B3-U0-G3
	Medium	140-180	30-35	10,000-18,000	Type II or III	B2-U0-G2
		180-220	30-35	15,000-19,000	Type II or III	B3-U0-G3
	Low	140-180	30-35	8,000-13,000	Type II or III	B2-U0-G2
		180-220	30-35	12,000-14,500	Type II or III	B2-U0-G2

ARTERIAL STREET - NON-CONTINUOUS STREET LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing an arterial street with non-continuous street. Street luminaires are to be placed in an opposite arrangement when not located at an intersection, Figures 19 and 20.

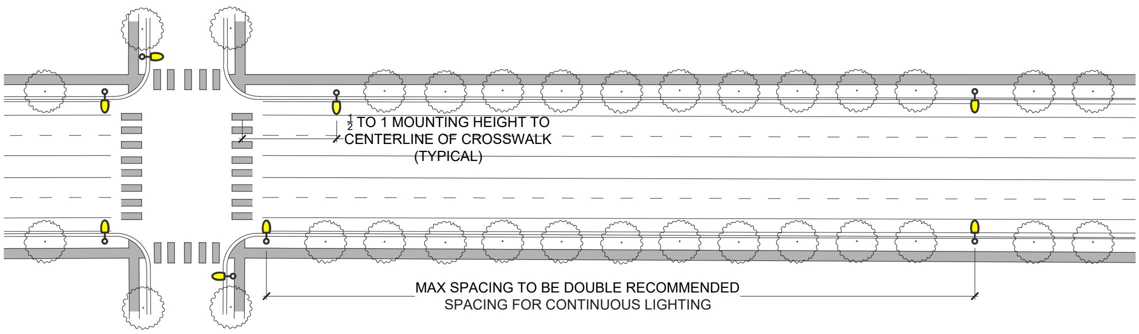

Figure 19: Typical Arterial with Non-Continuous Street Lighting Plan

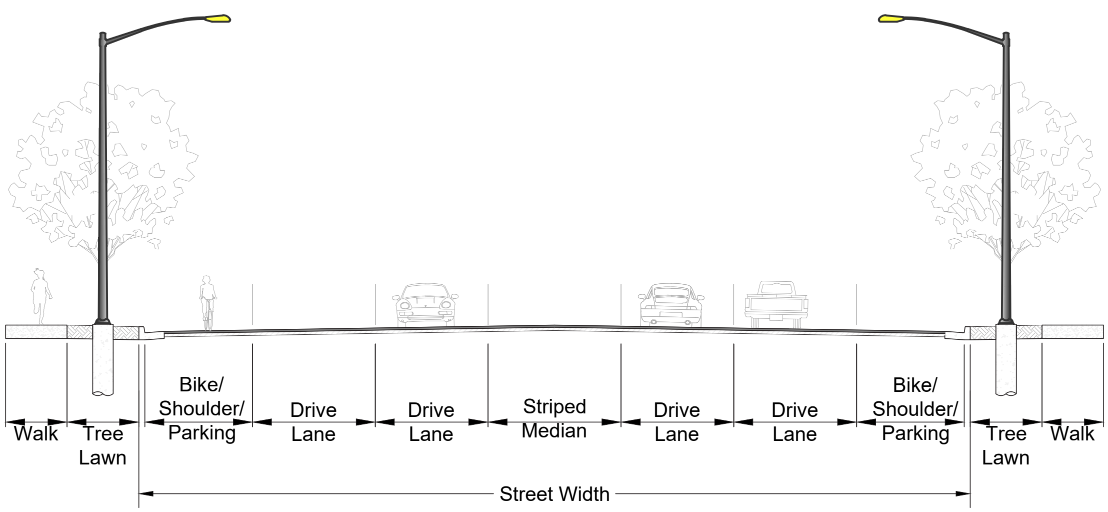

Figure 20: Typical Arterial with Non-Continuous Street Lighting Cross Section

TABLE 15: RECOMMENDED ARTERIAL (NON-MEDIAN MOUNTED) LUMINAIRE & POLE CRITERIA

STREET WIDTH	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
50-70	Medium	240-280	30-35	6,500-9,000	Type II or III	B2-U0-G2
		280-360	30-35	8,500-10,000	Type II or III	B2-U0-G2
	Low	360-440	30-35	6,000-8,500	Type II or III	B2-U0-G2
70-90	Medium	240-320	30-35	7,500-10,000	Type II or III	B2-U0-G2
		320-400	30-35	8,500-12,000	Type II or III	B3-U0-G2
	Low	280-360	30-35	6,500-9,500	Type II or III	B2-U0-G2
		360-440	30-35	7,500-11,000	Type II or III	B2-U0-G2
90-110	Medium	280-360	30-35	10,000-18,000	Type II or III	B2-U0-G2
		360-440	30-35	15,000-19,000	Type II or III	B3-U0-G3
	Low	280-360	30-35	8,000-13,000	Type II or III	B2-U0-G2
		360-440	30-35	12,000-14,500	Type II or III	B2-U0-G2

ARTERIAL STREET - CONTINUOUS STREET LIGHTING AND CONTINUOUS PEDESTRIAN LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing an arterial street with continuous street and pedestrian lighting. Street lights are to be placed in an opposite arrangement when not located at an intersection. Pedestrian lights should be coordinated with the landscape and street lighting layouts to maintain a consistent spacing, Figures 21 and 22.

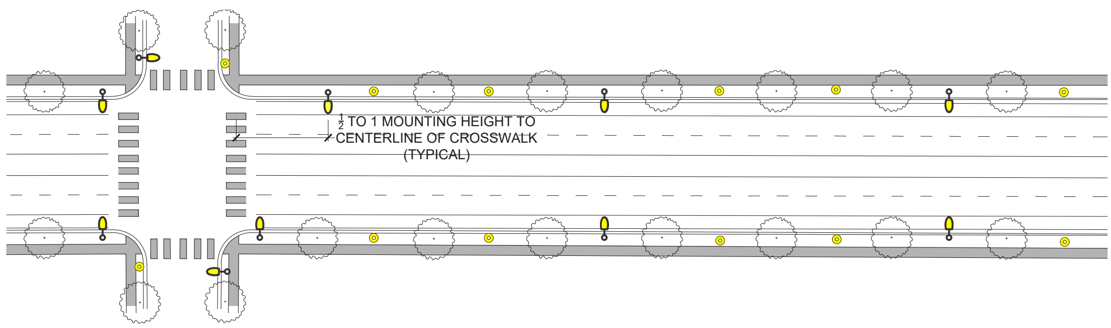

Figure 21: Typical Arterial with Continuous Street and Pedestrian Lighting Plan

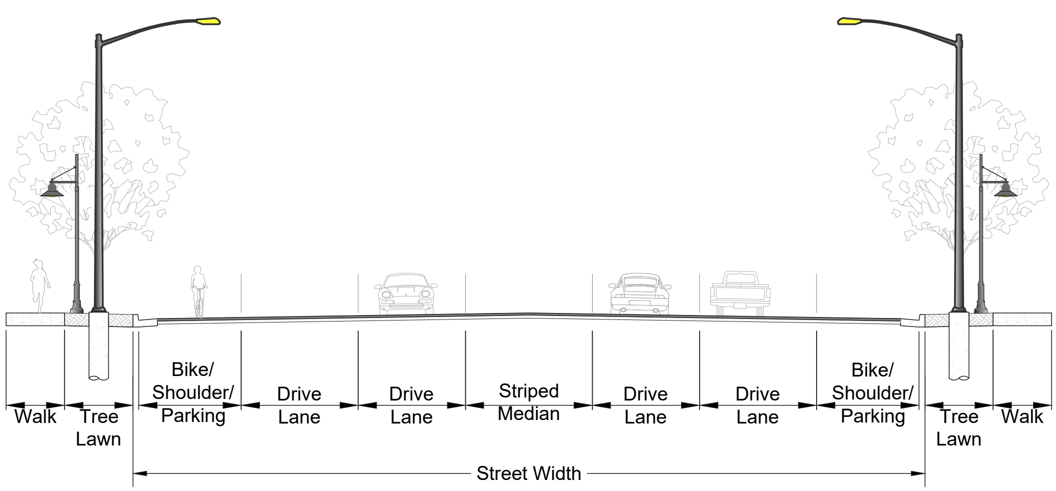

Figure 22: Typical Arterial with Continuous Street and Pedestrian Lighting Cross Section

TABLE 16: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	1.2	3:1	1.0

TABLE 17: RECOMMENDED ARTERIAL (NON-MEDIAN MOUNTED) STREET LUMINAIRE & POLE CRITERIA

STREET WIDTH	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
50-70	High	120-140	30-35	6,500-9,000	Type II or III	B2-U0-G2
		140-180	30-35	8,500-14,000	Type II or III	B3-U0-G2
70-90	High	140-180	30-35	8,500-12,000	Type II or III	B2-U0-G2
		180-220	30-35	12,000-18,000	Type II or III	B3-U0-G3
90-110	High	120-160	30-35	11,000-18,000	Type II	B3-U0-G3

TABLE 18: RECOMMENDED ARTERIAL (NON-MEDIAN MOUNTED) PEDESTRIAN LUMINAIRE & POLE CRITERIA

PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
High	50-80	12-15	3,000-5,500	Type II or III	B1-U2-G1

ARTERIAL STREET - CONTINUOUS STREET LIGHTING AND NON-CONTINUOUS PEDESTRIAN LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing an arterial street with continuous street lighting and non-continuous pedestrian lighting. Street luminaires are to be placed in an opposite arrangement when not located at an intersection. Pedestrian luminaire should be located to illuminate locations shadowed by trees or at vehicle-pedestrian conflict points, Figures 23 and 24.

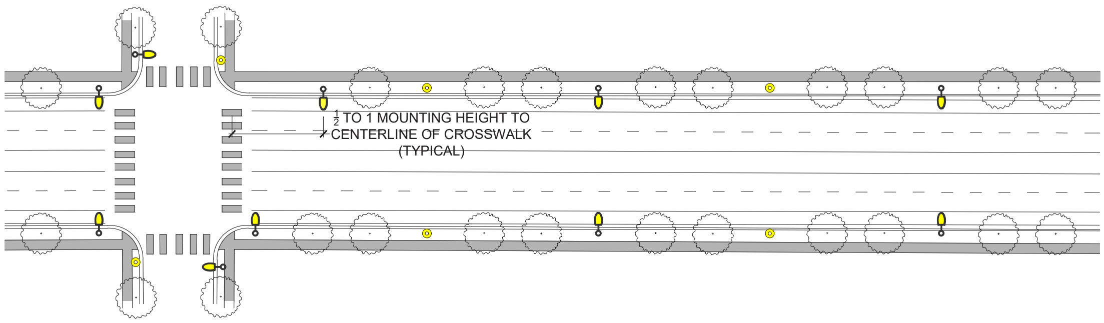

Figure 23: Typical Arterial with Continuous Street Lighting and Non-Continuous Pedestrian Lighting Plan

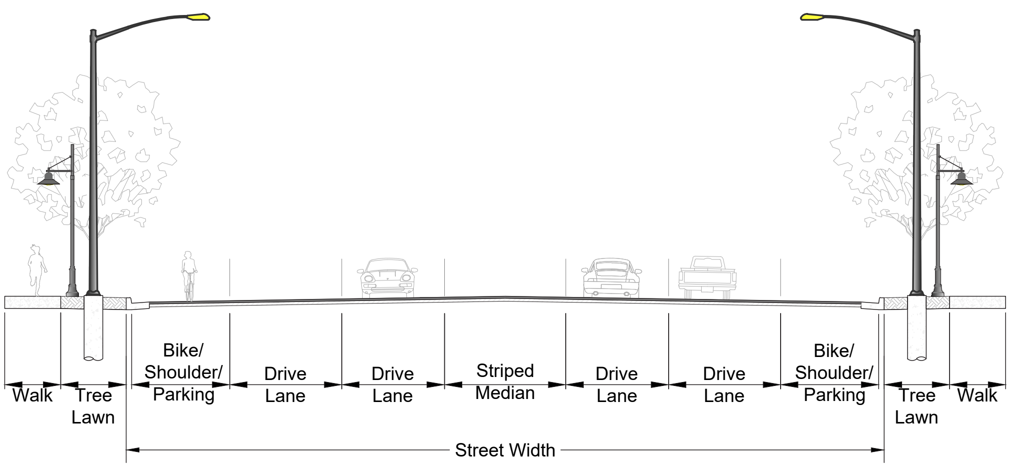

Figure 24: Typical Arterial with Continuous Street Lighting and Non-Continuous Pedestrian Lighting Cross Section

TABLE 19: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	1.2	3:1	1.0
Medium	0.9	3:1	0.5
Low	0.6	4:1	0.4

TABLE 20: RECOMMENDED ARTERIAL (NON-MEDIAN MOUNTED) LUMINAIRE & POLE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
50-70	High	120-140	30-35	6,500-9,000	Type II or III	B2-U0-G2
		140-180	30-35	8,500-14,000	Type II or III	B3-U0-G2
	Medium	140-180	30-35	6,500-9,000	Type II or III	B2-U0-G2
		180-220	30-35	8,500-10,000	Type II or III	B2-U0-G2
	Low	180-220	30-35	6,000-8,500	Type II or III	B2-U0-G2
70-90	High	140-180	30-35	8,500-12,000	Type II or III	B2-U0-G2
		180-220	30-35	12,000-18,000	Type II or III	B3-U0-G3
	Medium	120-160	30-35	7,500-10,000	Type II or III	B2-U0-G2
		160-200	30-35	8,500-12,000	Type II or III	B3-U0-G2
	Low	140-180	30-35	6,500-9,500	Type II or III	B2-U0-G2
		180-220	30-35	7,500-11,000	Type II or III	B2-U0-G2
90-110	High	120-160	30-35	11,000-18,000	Type II	B3-U0-G3
	Medium	140-180	30-35	10,000-18,000	Type II or III	B2-U0-G2
		180-220	30-35	15,000-19,000	Type II or III	B3-U0-G3
	Low	140-180	30-35	8,000-13,000	Type II or III	B2-U0-G2
		180-220	30-35	12,000-14,500	Type II or III	B2-U0-G2

TABLE 21: RECOMMENDED ARTERIAL (NON-MEDIAN MOUNTED) PEDESTRIAN LUMINAIRE & POLE CRITERIA

PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
High	50-80	12-15	3,000-5,500	Type II or III	B1-U2-G1
Medium	50-80	12-15	3,000-5,000	Type II or III	B1-U0-G1
	80-120	12-15	3,000-5,500	Type II or III	B1-U0-G1
Low	50-80	12-15	2,000-4,500	Type II or III	B1-U0-G1
	80-120	12-15	2,500-5,500	Type II or III	B1-U0-G1

ARTERIAL STREET - INTERSECTION ONLY LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing an arterial street with intersection only street lighting. Street luminaires are to be placed at the intersection with luminaire on half to one mounting height in front of any existing crosswalks, Figures 25 and 26.

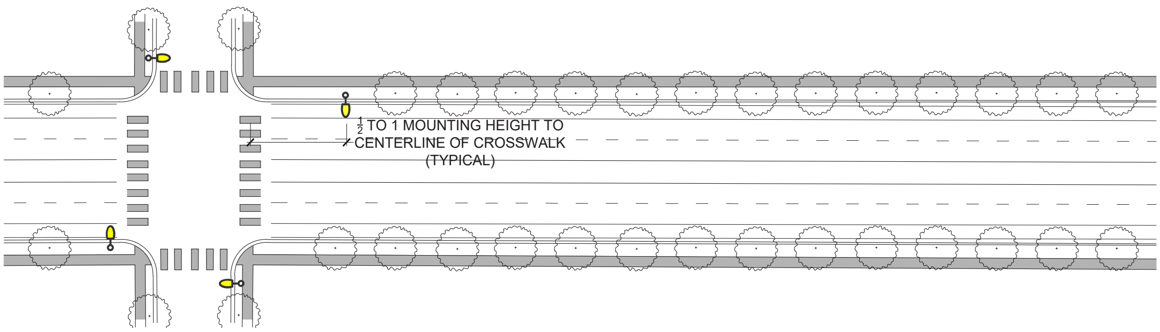

Figure 25: Typical Arterial with Street Lights at Intersections Only Plan

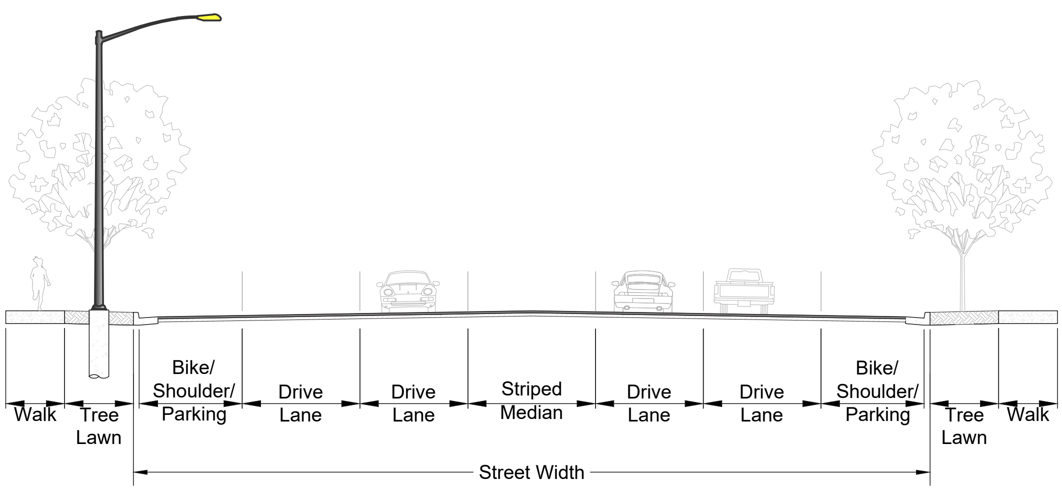

Figure 26: Typical Arterial with Street Lights at Intersections Only Cross Section

See Intersections & Crosswalks Section on page 14 for lighting criteria and luminaire recommendations.

COLLECTOR STREET - CONTINUOUS STREET LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with only street lighting. Luminaires are to be placed in an opposite arrangement when not located at an intersection, Figures 27 and 28.

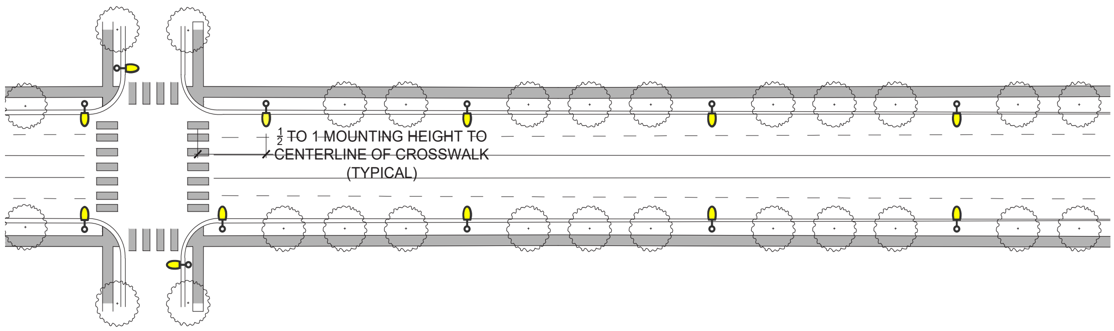

Figure 27: Typical Collector Street with Continuous Street Lighting

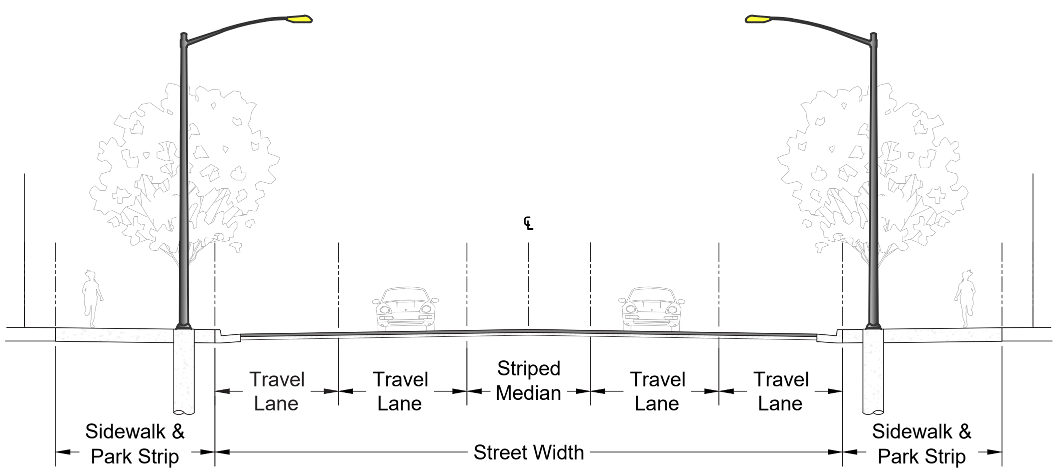

Figure 28: Typical Cross Section for Collector with Continuous Street Lighting

TABLE 22: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	0.8	3:1	1.0
Medium	0.6	4:1	0.5

TABLE 23: RECOMMENDED COLLECTOR STREET LUMINAIRE AND POLE SPACING CRITERIA

ROADWAY WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	140-160	30	6,500-7,800	Type II or III	B2-U0-G2
		180-220	30	7,000-10,000	Type II or III	B2-U0-G2
	Medium	140-160	30	5,000-7,000	Type II or III	B2-U0-G2
		180-220	30	6,500-8,800	Type II or III	B2-U0-G2
50-70	High	140-160	30	6,500-8,000	Type II or III	B2-U0-G2
		180-220	30	7,000-9,000	Type II or III	B2-U0-G2
	Medium	140-160	30	6,000-7,700	Type II or III	B2-U0-G2
		180-220	30	7,000-8,700	Type II or III	B2-U0-G2
70-100	High	120-140	30	8,500-12,000	Type II or III	B2-U0-G2
	Medium	140-160	30	7,000-10,000	Type II or III	B2-U0-G2
		180-220	30	9,000-13,000	Type II or III	B2-U0-G2

COLLECTOR STREET - NON-CONTINUOUS STREET LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with non-continuous street lighting. Luminaires are to be placed in an opposite arrangement when not located at an intersection, Figures 29 and 30.

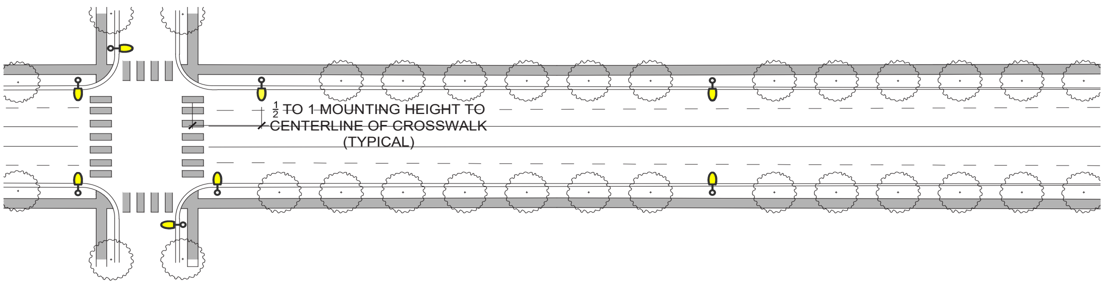

Figure 29: Typical Collector Street with Non-Continuous Street Lighting

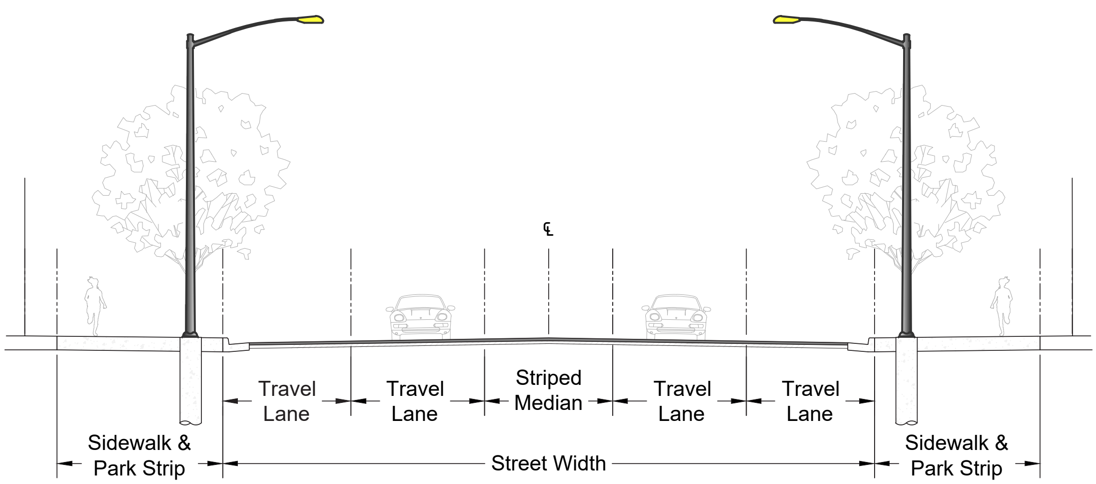

Figure 30: Typical Collector Street with Non-Continuous Lighting Cross Section

TABLE 24: RECOMMENDED COLLECTOR STREET LUMINAIRE AND POLE SPACING CRITERIA

ROADWAY WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	Medium	280-320	30	5,000-7,000	Type II or III	B2-U0-G2
		320-440	30	6,500-8,800	Type II or III	B2-U0-G2
	Low	280-360	30	4,000-5,500	Type III	B1-U0-G1
		360-440	30	4,500-6,000	Type III	B1-U0-G1
50-70	Medium	280-320	30	6,000-7,700	Type II or III	B2-U0-G2
		320-440	30	7,000-8,700	Type II or III	B2-U0-G2
	Low	280-320	30	4,000-5,500	Type II or III	B2-U0-G1
		320-440	30	5,000-8,000	Type II or III	B2-U0-G2
70-100	Medium	280-320	30	7,000-10,000	Type II or III	B2-U0-G2
		320-440	30	9,000-13,000	Type II or III	B2-U0-G2
	Low	280-360	30	6,500-9,000	Type II or III	B2-U0-G2
		360-440	30	6,500-10,000	Type II or III	B2-U0-G2

COLLECTOR STREET - CONTINUOUS STREET AND CONTINUOUS PEDESTRIAN LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with continuous street and pedestrian lighting. Street luminaires are to be placed in an opposite arrangement when not located at an intersection. Pedestrian lights should be coordinated with the landscape and street lighting layouts to maintain a consistent spacing, Figures 31 and 32.

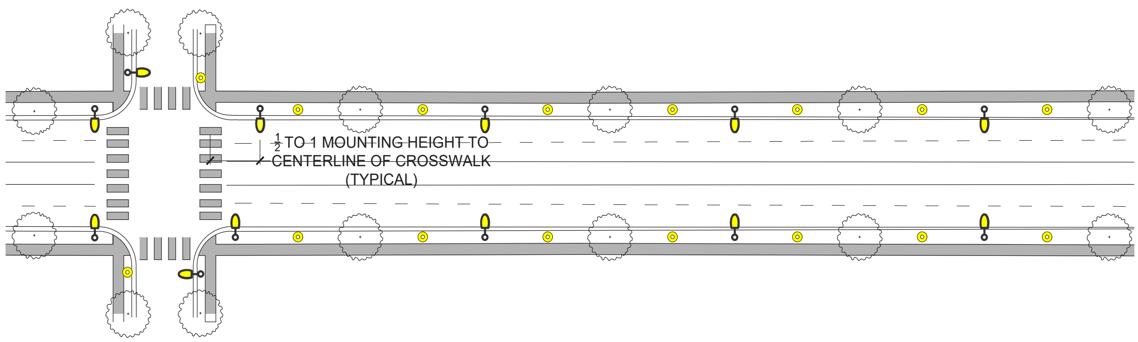

Figure 31: Typical Collector Street with Continuous Street and Pedestrian Lighting

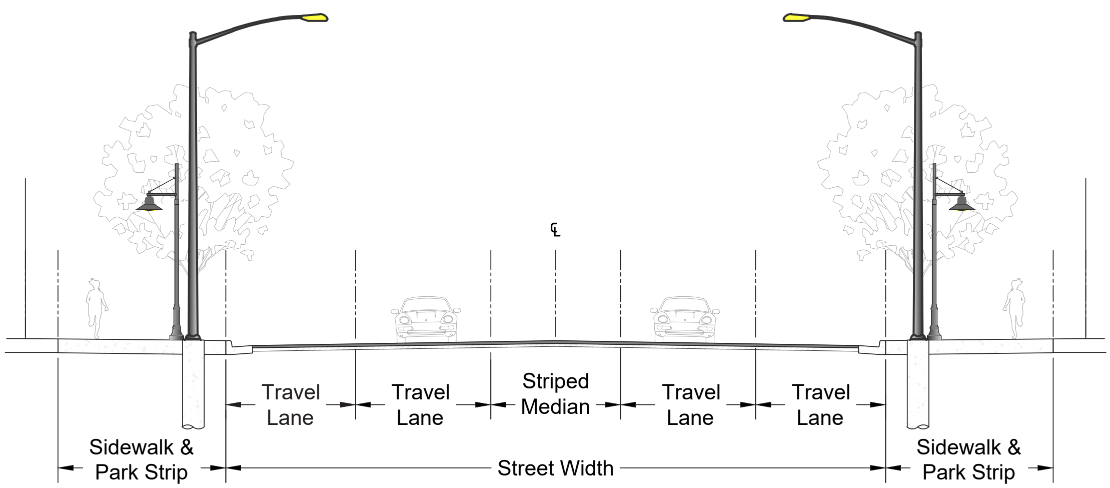

Figure 32: Typical Collector with Continuous Street and Pedestrian Lighting

TABLE 25: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	0.8	3:1	1.0

TABLE 26: RECOMMENDED COLLECTOR STREET LUMINAIRE AND POLE SPACING CRITERIA

ROADWAY WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	140-180	30	6,500-7,800	Type II or III	B2-U0-G2
		180-220	30	7,000-10,000		B2-U0-G2
50-70	High	140-160	30	6,500-8,000	Type II or III	B2-U0-G2
		160-220	30	7,000-9,000		B2-U0-G2
70-100	High	120-140	30	8,500-12,000	Type II or III	B2-U0-G2

TABLE 27: RECOMMENDED COLLECTOR PEDESTRIAN LUMINAIRE AND POLE SPACING CRITERIA

PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
High	50-80	12-15	3,000-5,000	Type II or III	B1-U2-G1
	80-120	12-15	3,500-5,500	Type II or III	B1-U2-G1

COLLECTOR STREET - CONTINUOUS STREET AND NON-CONTINUOUS PEDESTRIAN LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with continuous street lighting and non-continuous pedestrian lighting. Street luminaires are to be placed in an opposite arrangement when not located at an intersection. Pedestrian luminaire should be located to illuminate locations shadowed by trees or at vehicle-pedestrian conflict points, Figures 33 and 34.

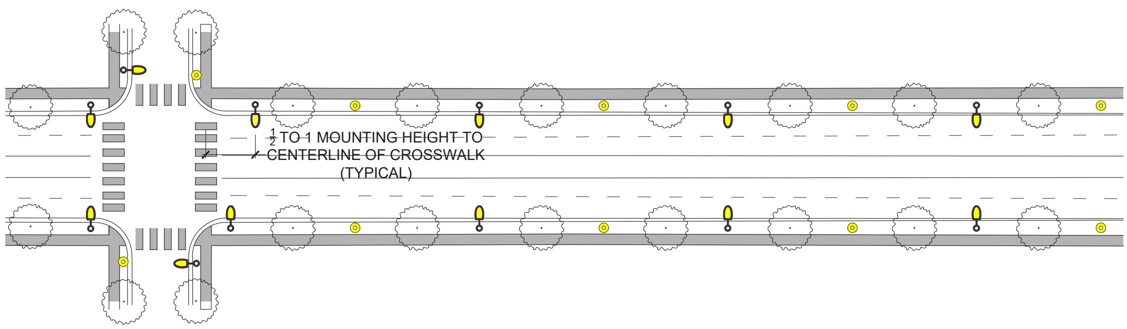

Figure 33: Typical Collector Street with Continuous Street and Non-Continuous Pedestrian Lighting Plan

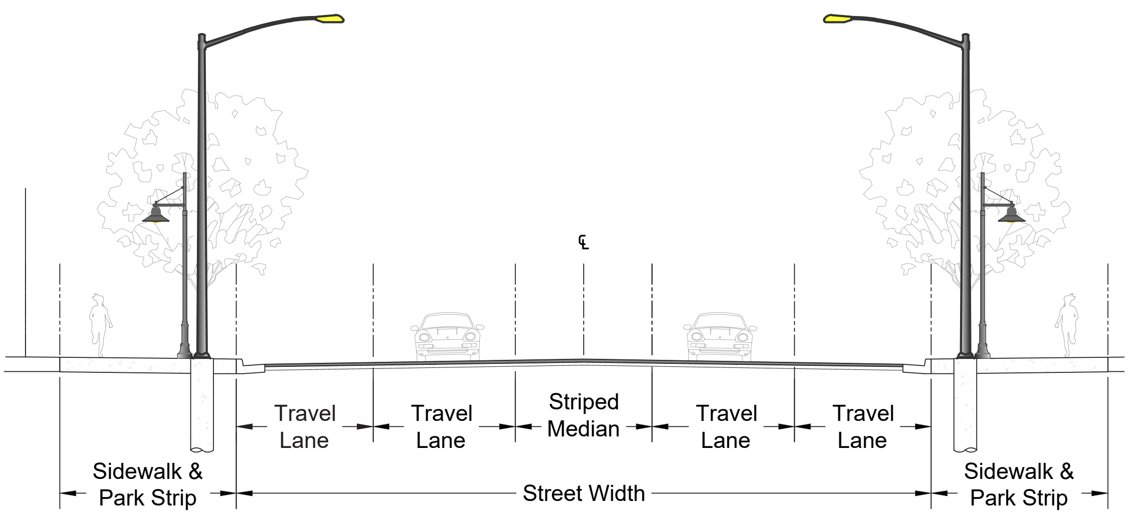

Figure 34: Typical Collector with Continuous Street and Non-Continuous Pedestrian Lighting Cross Section

TABLE 28: ARTERIAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	0.8	3:1	1.0
Medium	0.6	4:1	0.5

TABLE 29: RECOMMENDED COLLECTOR STREET LUMINAIRE AND POLE SPACING CRITERIA

ROADWAY WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	140-180	30	6,500-7,800	Type II or III	B2-U0-G2
		180-220	30	7,000-10,000	Type II or III	B2-U0-G2
	Medium	140-160	30	5,000-7,000	Type II or III	B2-U0-G2
		160-220	30	6,500-8,800	Type II or III	B2-U0-G2
50-70	High	140-160	30	6,500-8,000	Type II or III	B2-U0-G2
		160-220	30	7,000-9,000	Type II or III	B2-U0-G2
	Medium	140-160	30	6,000-7,700	Type II or III	B2-U0-G2
		160-220	30	7,000-8,700	Type II or III	B2-U0-G2
70-100	High	120-140	30	8,500-12,000	Type II or III	B2-U0-G2
	Medium	140-160	30	7,000-10,000	Type II or III	B2-U0-G2
		160-220	30	9,000-13,000	Type II or III	B2-U0-G2

TABLE 30: RECOMMENDED COLLECTOR PEDESTRIAN LUMINAIRE AND POLE SPACING CRITERIA

PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
High	50-80	12-15	3,000-5,000	Type II or III	B1-U2-G1
	80-120	12-15	3,500-5,500	Type II or III	B1-U2-G1
Medium	50-80	12-15	2,000-4,000	Type II or III	B1-U0-G1
	80-120	12-15	2,500-5,000	Type II or III	B1-U0-G1

COLLECTOR STREET - CONTINUOUS PEDESTRIAN LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with continuous pedestrian lighting. Pedestrian lights should be coordinated with the landscape and street lighting layouts to maintain a consistent spacing, Figures 35 and 36.

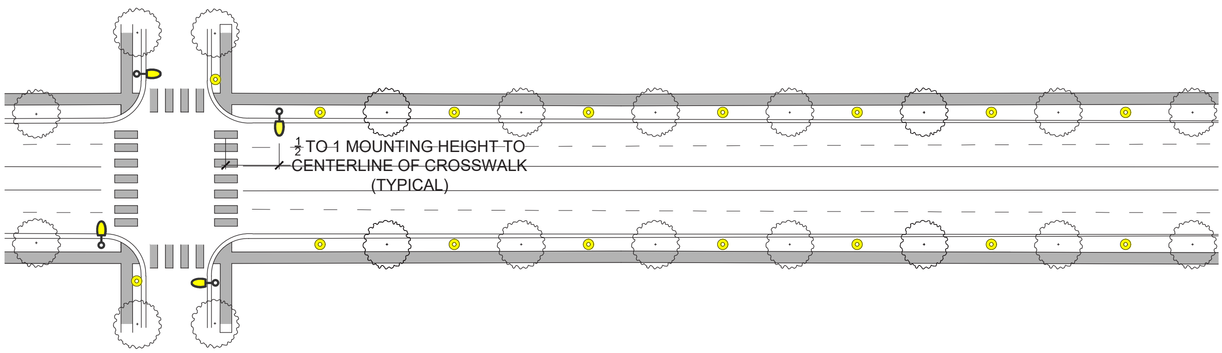

Figure 35: Typical Collector Street with Continuous Pedestrian Lighting

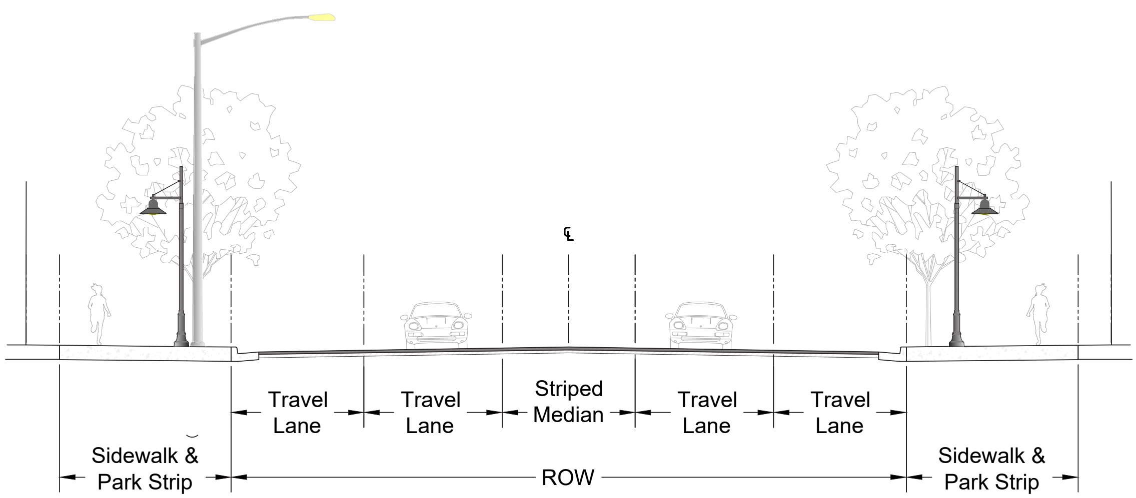

Figure 36: Typical Collector with Continuous Pedestrian Lighting

See Intersection Section on page 46 for intersection lighting criteria and luminaire recommendations.

TABLE 31: RECOMMENDED COLLECTOR PEDESTRIAN LUMINAIRE AND POLE SPACING CRITERIA

PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
High	50-80	12-15	3,000-5,000	Type II or III	B1-U0-G1
Medium	50-80	12-15	2,000-4,000	Type II or III	B1-U0-G1

COLLECTOR STREET - NON-CONTINUOUS PEDESTRIAN LIGHTING

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with street lighting at intersections and non-continuous pedestrian lighting. Street luminaires are to be placed at the intersection with luminaire on half to one mounting height in front of any existing crosswalks. Pedestrian luminaire should be located to illuminate locations shadowed by trees or at vehicle-pedestrian conflict points.

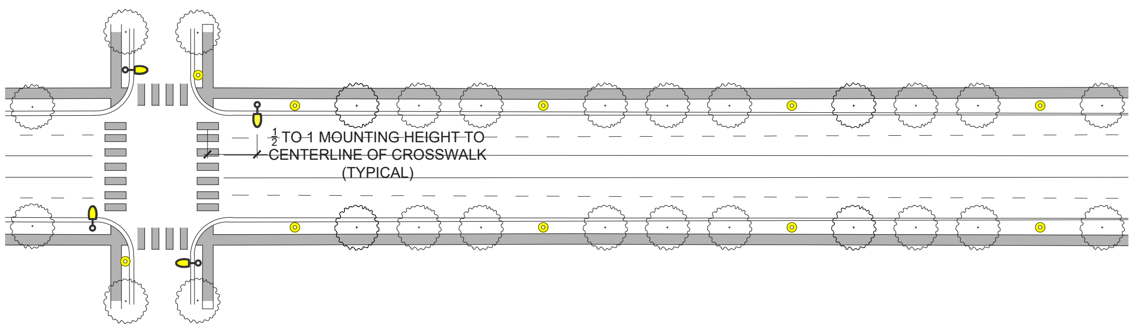

Figure 37: Typical Collector Street with Non-Continuous Pedestrian Lighting Plan

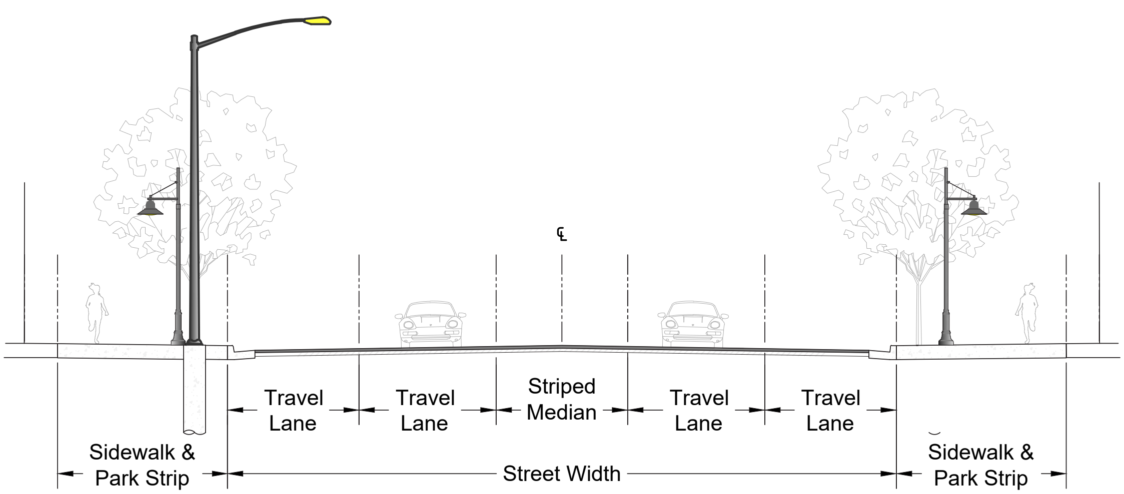

Figure 38: : Typical Collector with Non-Continuous Pedestrian Lighting Cross Section

See Intersections and Crosswalks section on page 14 for intersection lighting criteria and luminaire recommendations.

TABLE 32: RECOMMENDED COLLECTOR PEDESTRIAN LUMINAIRE AND POLE SPACING CRITERIA

PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
Medium	80-120	12-15	2,500-5,000	Type II or III	B1-U2-G1
Low	80-120	12-15	2,500-4,000	Type II or III	B1-U0-G1

COLLECTOR STREET - STREET LIGHTING AT INTERSECTIONS ONLY

The figures and tables below provide direction on the appropriate luminaire selection and non-median lighting layout when designing a collector street with street lighting at intersections and non-continuous pedestrian lighting. Street luminaires are to be placed at the intersection with luminaire on half to one mounting height in front of any existing crosswalks, Figures 39 and 40.

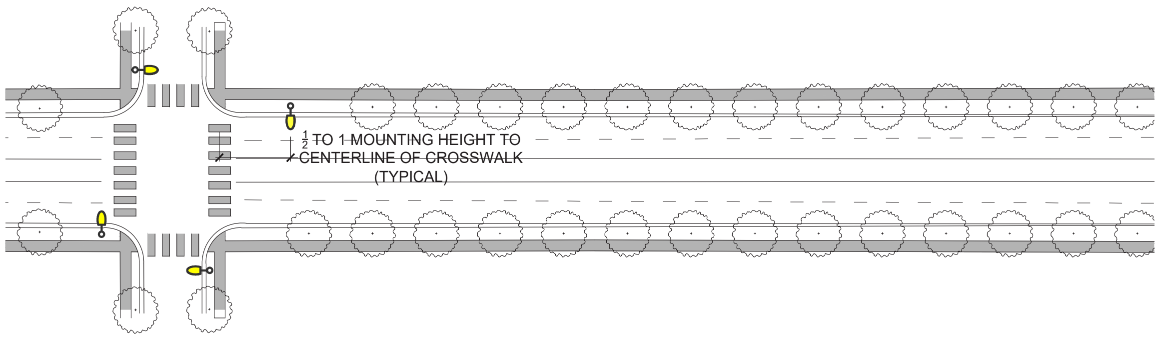

Figure 39: Typical Collector with Street Lighting at Intersections Only Plan

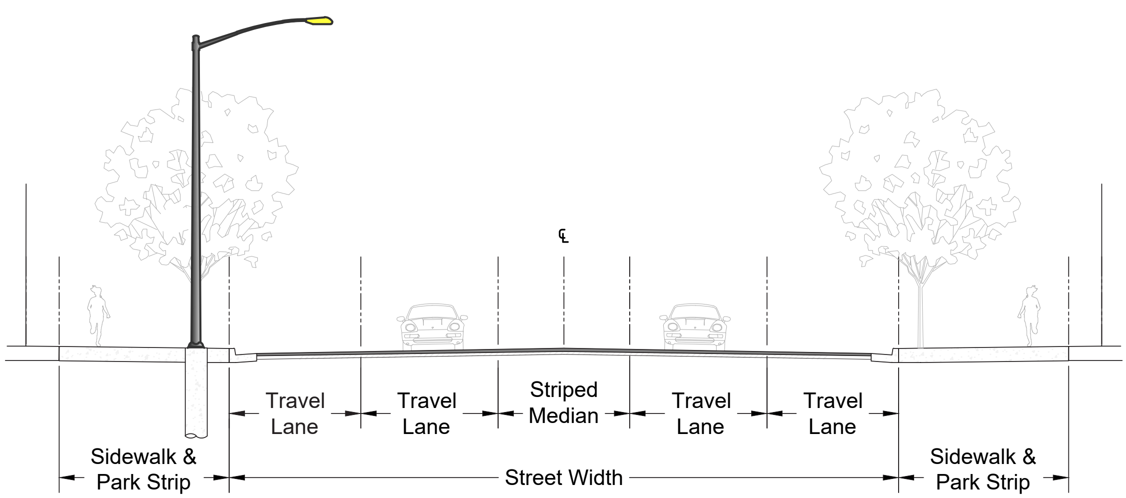

Figure 40: Typical Collector with Street Lighting at Intersections Only Cross Section

See Intersections & Crosswalks Section on page 14 for intersection lighting criteria and luminaire recommendations.

LOCAL STREET - CONTINUOUS STREET LIGHTING

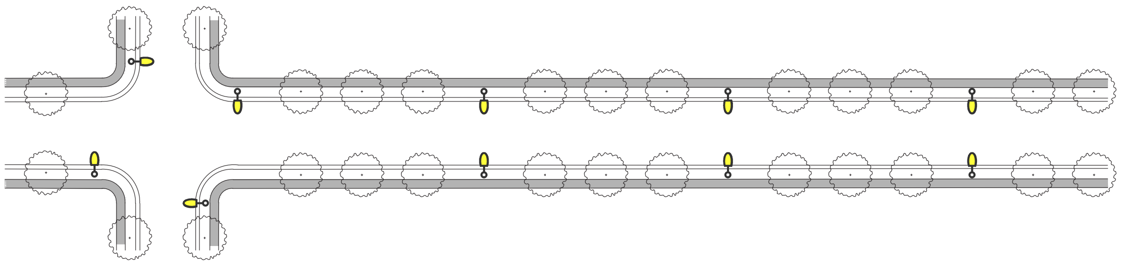

Figure 41: Typical Local Continuous Street Lighting Layout

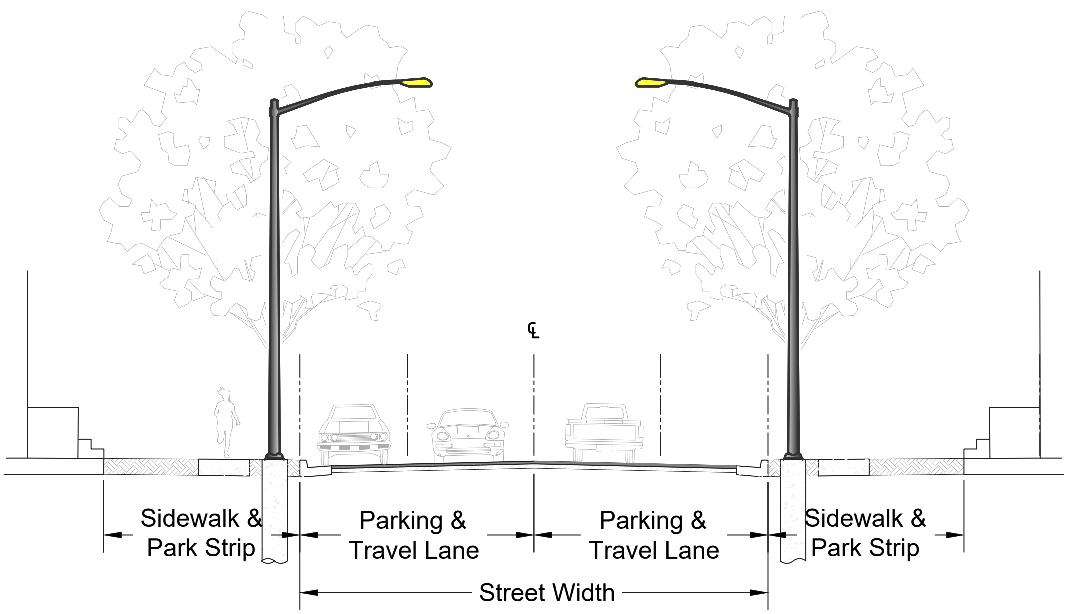

Figure 42: Typical Local Continuous Street Lighting Cross Section

TABLE 33: LOCAL STREET TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	ROADWAY		SIDEWALKS
	AVERAGE LUMINANCE (CD/M2)	LUMINANCE AVG:MIN RATIO	AVERAGE ILLUMINANCE (FC)
High	0.6	6:1	1.0

TABLE 34: RECOMMENDED LOCAL STREET LUMINAIRE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	140-180	30	4,500-5,500	Type II or III	B1-U0-G1
		180-220	30	4,500-7,750	Type II or III	B2-U0-G1
50-80	High	120-160	30	4,500-7,000	Type II or III	B1-U0-G1
		160-200	30	5,500-8,250	Type II or III	B2-U0-G1

LOCAL STREET - NON-CONTINUOUS STREET LIGHTING

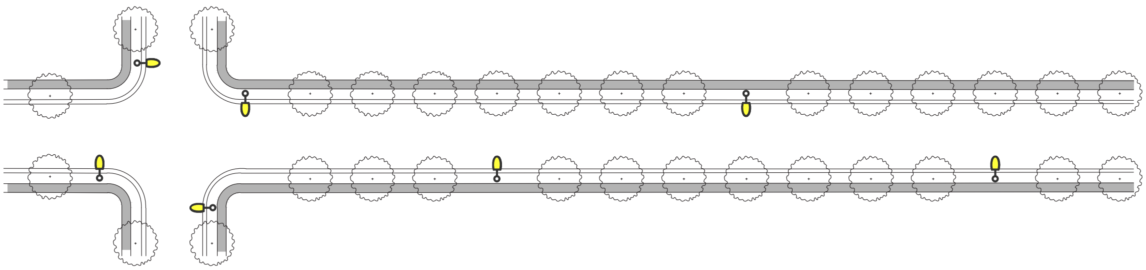

Figure 43: Typical Local Street with Non-Continuous Street Lighting Plan

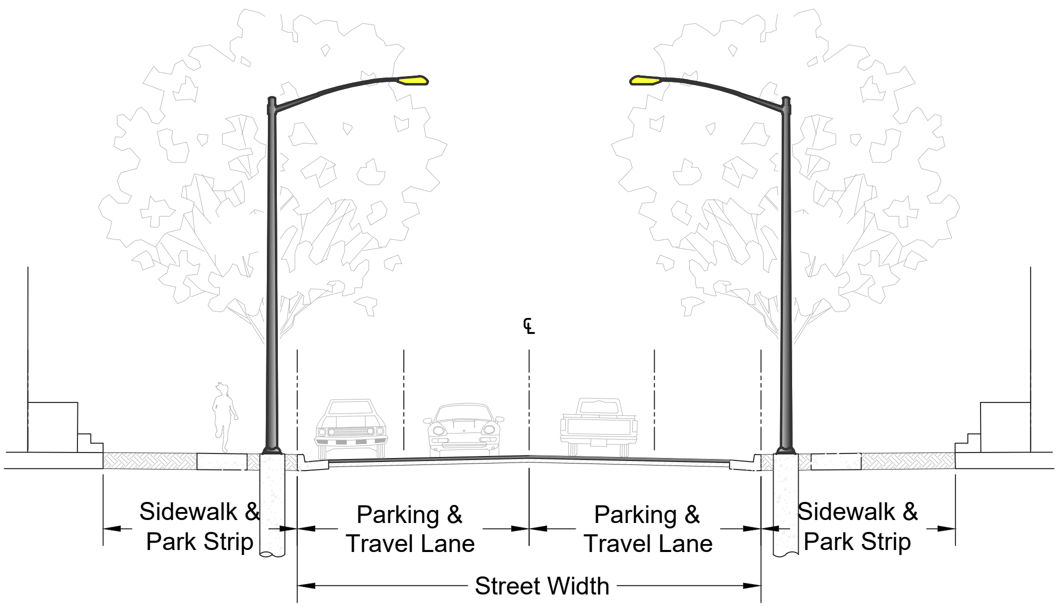

Figure 44: Typical Local Street with Non-Continuous Street Lighting Cross Section

TABLE 35: RECOMMENDED LOCAL STREET LUMINAIRE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	280-360	30	4,500-5,500	Type II or III	B1-U0-G1
		360-440	30	4,500-7,750	Type II or III	B2-U0-G1
	Medium	320-440	30	4,000-5,500	Type II or III	B1-U0-G1
50-80	High	240-320	30	4,500-7,000	Type II or III	B1-U0-G1
		320-400	30	5,500-8,250	Type II or III	B2-U0-G2
	Medium	300-400	30	4,500-6,000	Type II or III	B2-U0-G2

LOCAL STREET - NON-CONTINUOUS STREET LIGHTING AND CONTINUOUS PEDESTRIAN LIGHTING

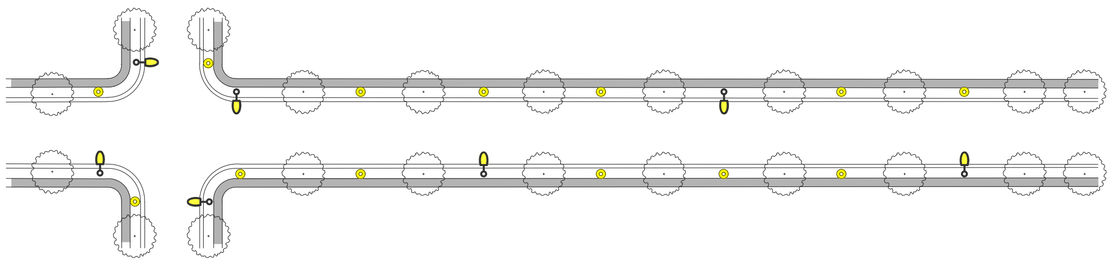

Figure 45: Typical Local Street with Non-Continuous Street and Continuous Pedestrian Lighting Plan

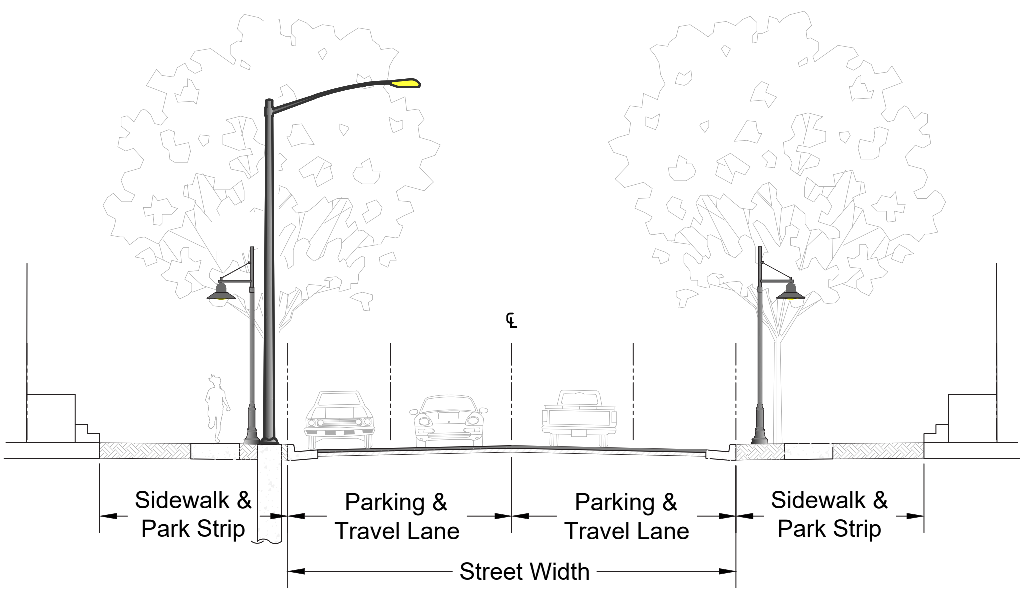

Figure 46: Typical Local Street with Non-Continuous Street and Continuous Ped Lighting Cross Section

TABLE 36: LOCAL SIDEWALK TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	SIDEWALKS
	AVERAGE ILLUMINANCE (FC)
High	1.0
Medium	0.5

TABLE 37: RECOMMENDED LOCAL STREET LUMINAIRE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	280-360	30	4,500-5,500	Type II or III	B1-U0-G1
		360-440	30	4,500-7,750	Type II or III	B2-U0-G1
50-80	High	240-320	30	4,500-7,000	Type II or III	B1-U0-G1
		320-400	30	5,500-8,250	Type II or III	B2-U0-G2

TABLE 38: RECOMMENDED LOCAL PEDESTRIAN LUMINAIRE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	60-90	12	2,500-4,000	Type II or III	B1-U0-G1
		90-120	12	4,000-5,500	Type II or III	B1-U0-G1
50-80	High	60-90	12	3,500-5,500	Type II or III	B1-U0-G1

LOCAL STREET -CONTINUOUS PEDESTRIAN LIGHTING

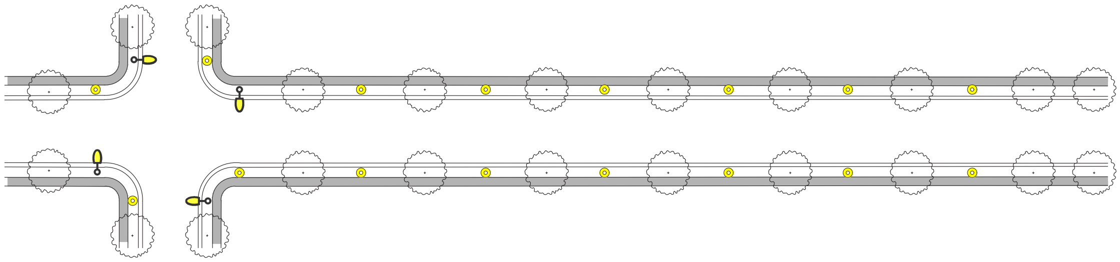

Figure 47: Typical Local Street with Continuous Pedestrian Lighting Plan

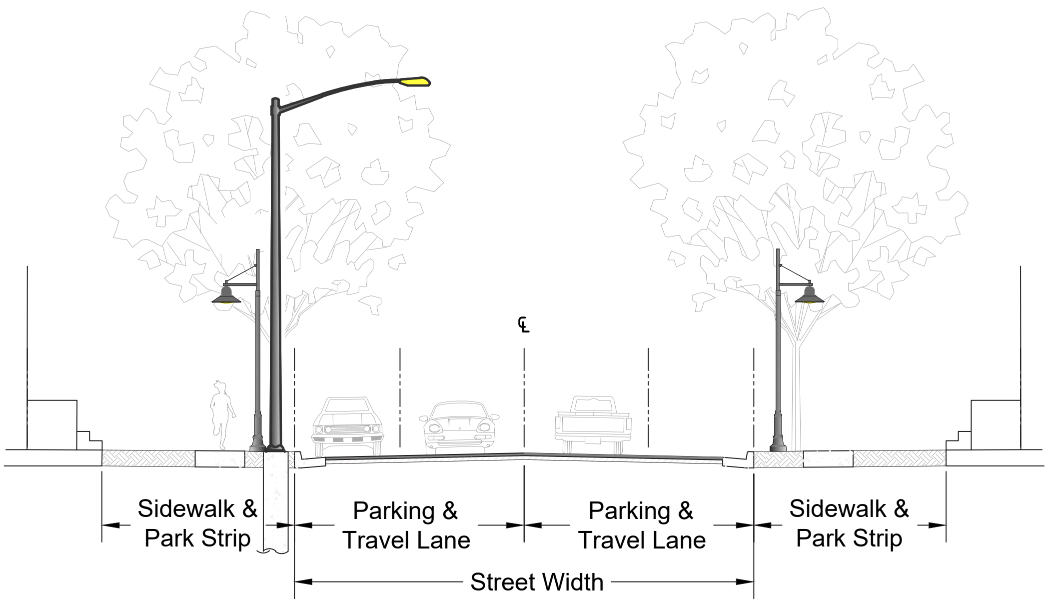

Figure 48: Typical Local Street with Continuous Pedestrian Lighting Cross Section

See Intersections and Crosswalks section on page 14 for intersection lighting criteria and luminaire recommendations.

TABLE 39: LOCAL SIDEWALK TARGET CRITERIA PER IES RP-8-18

PEDESTRIAN ACTIVITY	SIDEWALKS
	AVERAGE ILLUMINANCE (FC)
High	1.0
Medium	0.5

TABLE 40: RECOMMENDED LOCAL PEDESTRIAN LUMINAIRE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	High	60-90	12	2,500-4,000	Type II or III	B1-U0-G1
		90-120	12	4,000-5,500	Type II or III	B1-U0-G1
	Medium	60-90	12	2,500-3,500	Type II, III, or IV	B1-U0-G1
		90-120	12	3,500-5,500	Type II, III, or IV	B1-U0-G1
50-80	High	60-90	12	3,500-5,500	Type II or III	B1-U0-G1
	Medium	60-90	12	4,000-5,550	Type II or III	B1-U0-G1

LOCAL STREET - NON-CONTINUOUS PEDESTRIAN LIGHTING

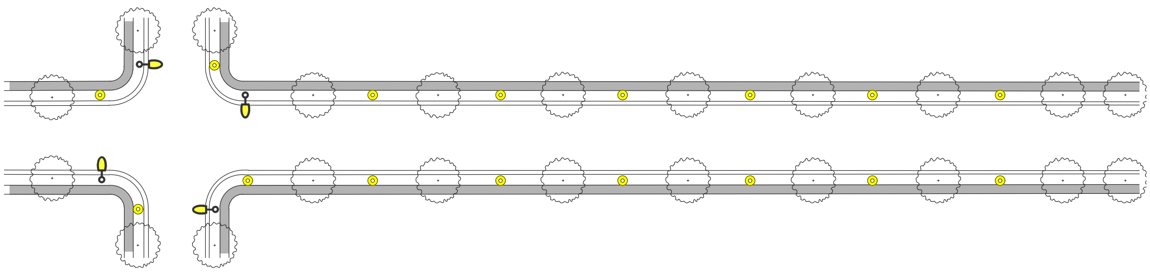

Figure 49: Typical Local Street with Non-Continuous Pedestrian Lighting Plan

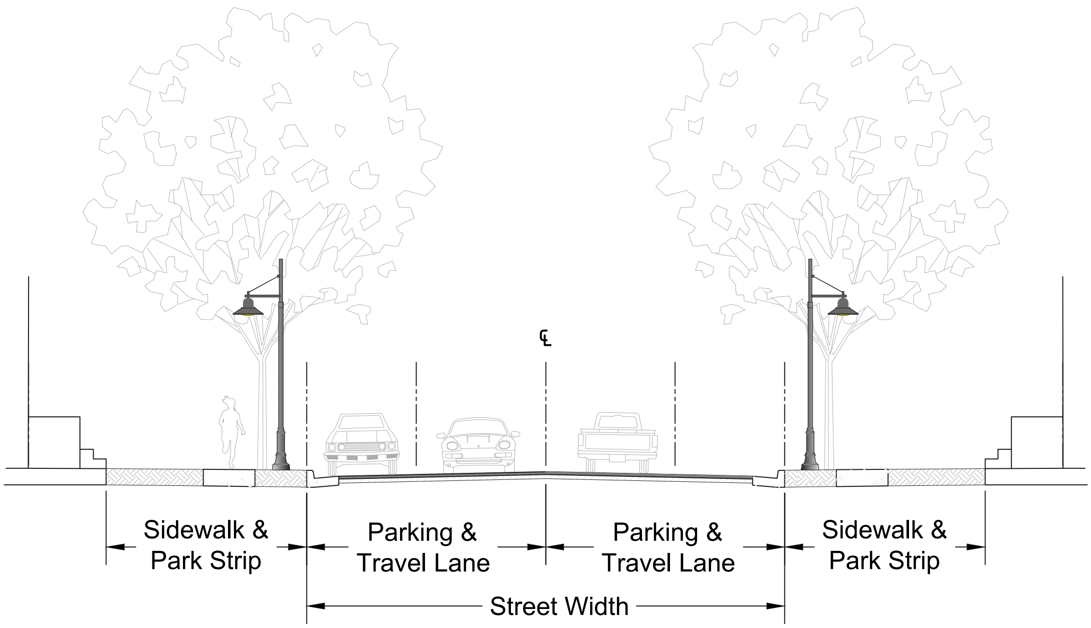

Figure 50: Typical Local Street with Non-Continuous Pedestrian Lighting Cross Section

See Intersections and Crosswalks section on page 14 for intersection lighting criteria and luminaire recommendations.

TABLE 41: RECOMMENDED LOCAL PEDESTRIAN LUMINAIRE CRITERIA

STREET WIDTH (FT)	PEDESTRIAN ACTIVITY	POLE SPACING (FT)	POLE HEIGHT (FT)	LUMEN OUTPUT (LM)	TYPICAL PHOTOMETRIC DISTRIBUTION	MAX. BUG RATING
30-50	Medium	120-180	12	2,500-3,500	Type II, III, or IV	B1-U0-G1
		180-240	12	3,500-5,500	Type II, III, or IV	B1-U0-G1
	Low	120-240	12	2,000-4,000	Type II, III, or IV	B1-U0-G1
50-80	Medium	120-180	12	4,000-5,550	Type II or III	B1-U0-G1
	Low	160-240	12	2,500-4,000	Type II, III or IV	B1-U0-G1

LOCAL STREET - INTERSECTION ONLY LIGHTING

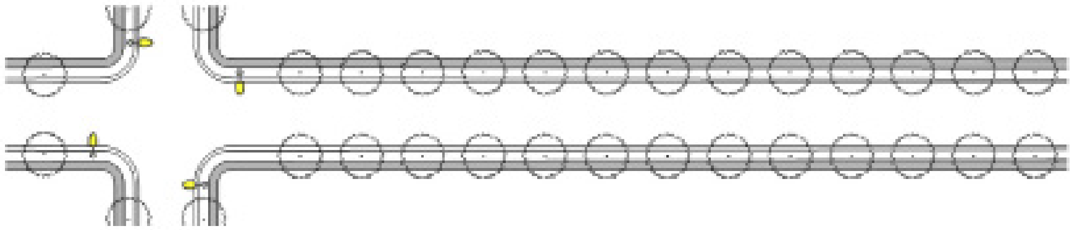

Figure 51: Typical Local Street Intersection Only Lighting Plan

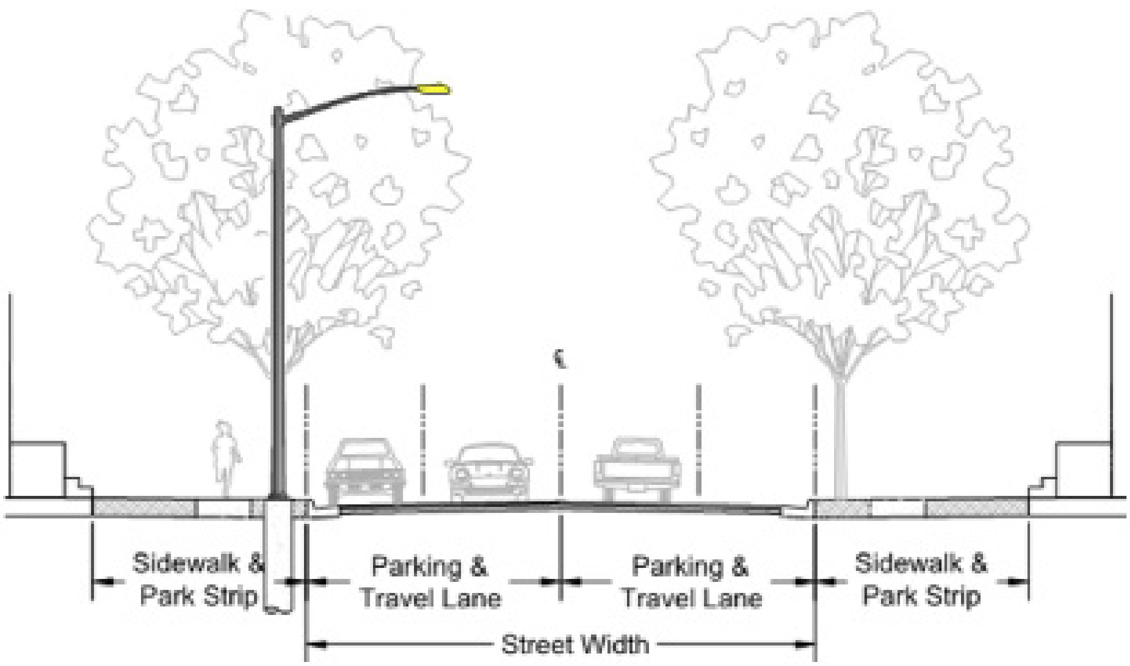

Figure 52: Typical Local Street with Intersection Only Lighting Cross Section

See Intersections and Crosswalks section on page 14 for intersection lighting criteria and luminaire recommendations.

BUS STOP LIGHTING

UNCOVERED BUS STOP

Uncovered bus stops should be lit by a street luminaire positioned 1/2 to 1 mounting height from the bus stop in the direction of oncoming traffic. The illuminance criteria at bus stops are found in Table 42.

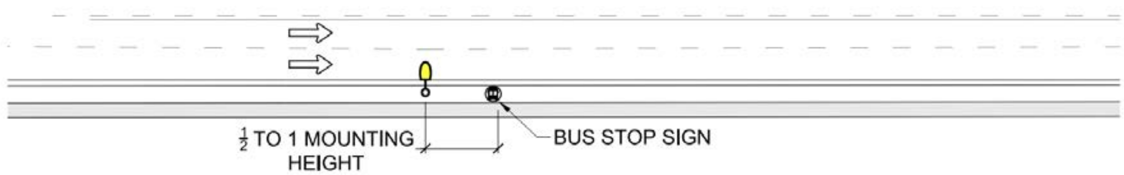

Figure 53: Uncovered Bus Stop Lighting Layout

BUS SHELTERS

Bus Shelters criteria are found in Table 42. Vertical illuminance aids in facial recognition and visible comfort and is to be measured 5 ft. above the ground. Street luminaires within 100 ft of bus shelters increase ambient light and visual comfort.

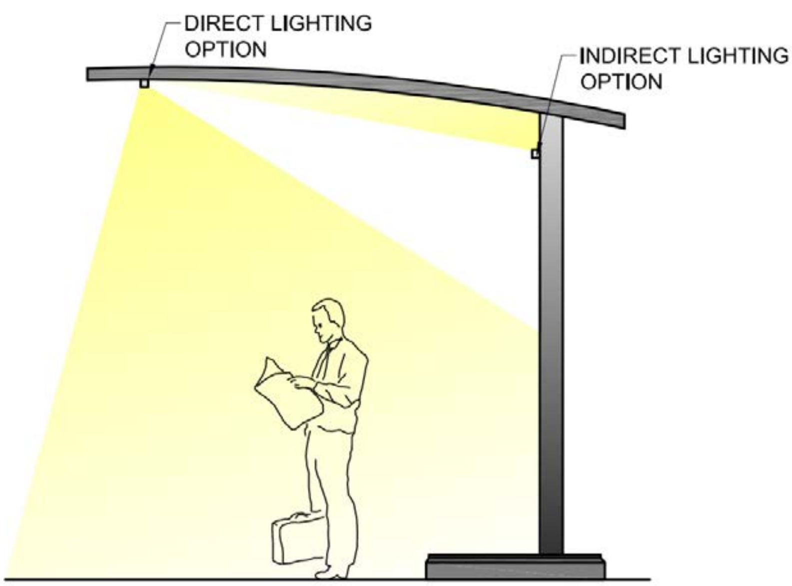

Figure 54: Covered Bus Stop Lighting Section

TABLE 42: LOCAL SIDEWALK TARGET CRITERIA PER IES RP-8-18

BUS STOP CRITERIA	HORIZONTAL ILLUMINANCE (FC)	VERTICAL ILLUMINANCE (FC)
Uncovered Bus Stop	1.0	0.2
Covered Bus Stop	1.0	1.0

MINIMAL IMPROVEMENTS

CONFIRM EXISTING CONDITIONS

Current existing conditions where improvements are being made should be evaluated prior to beginning lighting improvement design. One-for-one replacements should be done where the existing lighting strategy meets the required lighting strategy in the Lighting Warrants Table 1-3. If the existing lighting strategy is appropriate, the spacing of the existing lights should be upgraded to meet the lumen requirements for the specific type and land use and the necessary infrastructure, such as wiring, foundation, and poles are all in good condition. If the lighting strategy in the area requires additional street or pedestrian lights, supplemental improvements will need to be made. Supplemental improvements may also need to be made if the spacing is not met or there are infrastructure issues.

SUPPLEMENTAL IMPROVEMENTS

Supplemental improvements entail adding a limited quantity of new street or pedestrian light locations to the existing lighting system to illuminate any dark areas on the street. If any of the following conditions exist, then the improvement area should follow the comprehensive improvement methodology:

- The existing lighting on the block does not meet the lighting strategy in Tables 1-3: Lighting Warrants and additional pedestrian or streetlights are necessary to comply with the appropriate lighting strategy.
- Existing street or pedestrian light spacing exceeds two times the recommended value based on lighting strategy.
- Lighting only exists on one side of the street and does not sufficiently light the whole street.

To maintain consistency in the lighting design, all luminaires used in supplemental improvements should match the luminaires chosen for 1-for-1 replacements.

ONE-FOR-ONE REPLACEMENT

Salt Lake City is upgrading existing HID lights to new energy efficient LEDs. The new replacement lights should meet the lighting criteria set forth in the Luminaire Criteria Tables based on street classification, adjacent land use and pedestrian conflict. The City is also working to upgrade any previously installed LEDs that are not within the luminaire specification and are causing obtrusive glare and light trespass to a luminaire that is more appropriate to the specific location. All one-for-one replacements should match the appreciate color temperature based on adjacent land use and existing LEDs that do not meet the appropriate CCT should be considered for replacement.

LIGHTING CONTROLS AND ADAPTIVE DIMMING STRATEGIES

As part of the lighting upgrades throughout the city, the new LED lights will be compatible with a city-wide wireless lighting control system. This lighting control system will allow Salt Lake City to have precise control over each individual light throughout the City, enabling the City to raise or lower light levels when needed or desired. Dimming strategies will vary throughout the City based on adjacent land use, pedestrian conflicts, and time of day to ensure vehicle and pedestrian safety while working to minimize light pollution and light trespass.

When dimming lighting in a certain area, the lighting strategy must be considered, speed limit on the streets, and vehicle and pedestrian volumes.

- When dimming continuous street or pedestrian lighting, the first strategy is to dim from high or medium pedestrian criteria to medium or low pedestrian criteria. If continuous lighting is already in a low pedestrian area, research supports that when using broad spectrum LED sources, dimming to 70% of current output or lower can still provide sufficient lighting. If the City is interested in dimming below a low pedestrian criteria for a certain continuously lighted street, the City should undergo a public engagement pilot study with residents, city council, police, fire, and the city attorney to further understand the implications of reduced lighting in the area.
- Along streets with non-continuous street and pedestrian lighting, there is not a required lighting criteria and lights should be dimmed to comfortable levels while still maintaining the desired effect of the lighting design.

DIMMING IN RESIDENTIAL AREAS:

All street classifications are found in all single-and multi-family residential areas in Salt Lake City. The Table below summarizes the recommended dimming strategies based on street classification, and pedestrian conflict.

TABLE 43: RECOMMENDED DIMMING STRATEGIES FOR RESIDENTIAL AREAS

	ARTERIAL STREET	COLLECTOR STREET	LOCAL STREET
Multifamily Residential (Med Ped Conflict)	Dim Street and Pedestrian Lights to Low Ped Conflict	Dim Street and Pedestrian Lights to Low Ped Conflict	Dim Street and Pedestrian Lights to Low Ped Conflict
Single Family Residential (Low Ped Conflict)	*Dim Street and Pedestrian Lights to Comfortable Light Levels	*Dim Street and Pedestrian Lights to Comfortable Light Levels	*Dim Street and Pedestrian Lights to Comfortable Light Levels

*Dimming to comfortable light levels below the Low Pedestrian Criteria requires a public engagement process.

DIMMING IN DOWNTOWN RESTAURANT/RETAIL ENVIRONMENTS

It is essential to maintain proper light levels based on pedestrian conflict when adjusting light levels in the downtown. Pedestrian traffic fluctuates based on the night of the week, as well as the time of day. If an event is happening within a public gathering space or venue, higher pedestrian volume should be expected, and the recommended dimming strategy should be overruled and the areas surrounding the event center should be lighted to criteria. The table below shows the dimming strategies based on night of the week and time of night.

TABLE 44: RECOMMENDED DIMMING STRATEGIES FOR DOWNTOWN

		DIMMING STRATEGY
Sunday Night - Wednesday Night	Dusk to 10PM	Light to Criteria
	10PM to Midnight	Reduce Criteria to a Lower Pedestrian Conflict
	Midnight to 2:30AM	Reduce Criteria to Low Pedestrian Conflict or to Comfortable Light Levels
	2:30AM to Dawn	Reduce Criteria to Low Pedestrian Conflict or to Comfortable Light Levels
Thursday Night - Saturday Night	Dusk to 10PM	Light to Criteria
	10PM to Midnight	Reduce Criteria to a Lower Pedestrian Conflict
	Midnight to 2:30AM	Light to Criteria
	2:30AM to Dawn	Reduce Criteria to Low Pedestrian Conflict or to Comfortable Light Levels

*Dimming to comfortable light levels below the Low Pedestrian Criteria requires a public engagement process

DIMMING INTERSECTION AND MID-BLOCK CROSSINGS

Intersections and mid-block crossing should be dimmed separately from the rest of the streetlights; however, the same strategy should be used. If the intersection or crossing has less traffic at certain times throughout the night, the criteria can be reduced to a lower pedestrian conflict criteria. If further reduction in light levels are desired, a similar public engagement process should be done to ensure the safety of pedestrians and vehicles at intersection and mid-block crossings.

LUMINAIRE SPECIFICATIONS

Luminaire specifications are found in Tables 55 & 56

TABLE 55: SPECIFICATION OVERVIEW

CONTROLS	ELECTRICAL SYSTEM
Integral 0-10V dimmable drivers to adjust light levels. All streetlights will be installed with an ANSI 7 pin photocell receptacle to be compatible with wireless controls in the future.	Single phase 120/240V electrical system voltage.
LIGHT STANDARD SPECIFICATION	**LIGHT STANDARD FOUNDATIONS**
The light standard - also referred to as the pole - should be tapered, round galvanized steel with a 12-inch bolt circle. Color match the head and arm of the pole. Design replacement poles, heads, and/or arms to match existing color and type of adjacent poles if appropriate and with written City approval. City approval of decorative or non-standard poles is required. Painted over galvanized is required for any pole requiring color change. All new mast arm installations are required to be 2, 6, or 10 feet. The City must approve all poles with banner arms and power receptacles.	City standard design for all precast concrete or poured-in-place light standard foundations. While the City accepts poured-in-place foundations, precast concrete foundations are preferred and should be installed whenever possible.

TABLE 56: LUMINAIRE SPECIFICATIONS

LUMINAIRE	Correlated Color Temperature (CCT)	3000K Maximum
	Color Rendering Index (CRI)	≥65 in most areas, or > 40 in Critical Wildlife Habitat
	Luminaire Lumen Range	The lumen output should comply with the lumen range specified in the Recommended Luminaire Criteria Tables based on street classification, adjacent land use and pedestrian conflict. Criteria for luminaire CCT are found in Volume 1 Table 5.
	Luminaire Finish	Die cast aluminum housing with fade and abrasion resistant polyester powder coat finish. Finish should match existing color of luminaires along street.
	Luminaire Warranty	10 years on luminaire and components.
	Luminaire Warranty Period	Earliest warranty period allowed starts on the date of receipt by City.
	Luminaire Identification	Luminaire external label per ANSI C136.15, and an interior label per ANSI C136.22 required.
	Operation and Storage Temperature	'-40°C to +40°C.
	Frequency Vibration	'Luminaire should withstand low and high frequency vibration, per ANSI C136.31, over the rated life of the light source.
	Minimum Rated Life	70,000 hours minimum at 55°C, per IES TM-21
	IP rating	IP65 or greater.
	Voltage	120/277.
	Control	Dimmable and installed with ANSI 7 pin photo receptacle to be compatible with wireless luminaires controls in the future.
	Cooling System	Passive utilizing heat sinks, convection, or conduction. Upper surfaces required to shed precipitation. Cooling fans are not allowed.
	Photocontrol	Individual multi-contact 7-pin twist lock receptacle per ANSI C136.41. Or control module.
	Electrical Immunity	Luminaire are required to meet the performance requirements specified in ANSI C136.2 for dielectric withstand, using the DC test level and configuration.
LED DRIVERS	Power Factor (PF)	Minimum of 0.9 at full input power.
	Total Harmonic Distortion (THD)	Maximum of 20 percent at full input power.
	Restriction of Hazardous Substances (RoHS)	Restriction of Hazardous Substances (RoHS) compliant drivers required.
	Surge Protection	Protection from all electrical surges with an elevated electrical immunity rating, including but not limited to lightning strikes and stray current in rebar and concrete required for all LEDs. Integral surge protection to the LED power supply required. "Elevated" (10kV/10kA) requirements per IEEE/ANSI C62.41.2 for luminaire. Manufacturer indication of failure of the electrical immunity system can possibly result in disconnect of power to luminaire required.
	Total Power Consumed in Off State	Maximum 8 watt off-state power consumption for luminaire, including driver.
	Electromagnetic interference	Electromagnetic interference: Compliance with Federal Communications Commission (FCC) 47 Code of Federal Regulations (CFR) part 15 non-consumer radio frequency interference (RFI) and/or electromagnetic interference (EMI) standards.

LIGHTING CALCULATIONS

PURPOSE

Lighting design calculations for new installations is an iterative process. The use of lighting models to calculate the luminance along streets and illuminance on sidewalks is the most efficient and accurate way to design to criteria. Light trespass calculations should also be included to limit the amount of obtrusive light in the City. This section describes the required calculations to ensure that all criteria is met for all new installations.

HOW TO SET UP A CALCULATION

The following sections document the parameters and considerations when calculating street lighting levels.

IES FILES

The first step in running a calculation is to find and download the photometric in IES file format for the specific luminaire being considered. This file is available on the manufacturer's website and can be downloaded into any lighting calculation simulation software. The IES file will contain all information for the luminaire, such as lumen output, color temperature, wattage, distribution, and voltage.

LIGHT LOSS FACTOR FOR LED

A light loss factor should be applied to every luminaire considered, to ensure that the maintained light levels will meet the target criteria. Table 57, below, lists typical light loss factors for LEDs and legacy products found throughout Salt Lake City.

TABLE 57: TYPICAL LIGHT LOSS FACTORS

LIGHT SOURCE	LUMINAIRE DIRT DEPRECIATION (LDD)	LUMINAIRE LUMEN DEPRECIATION (LLD)	TOTAL LIGHT LOSS FACTOR (LLF)
LED	0.9	0.9[7]	0.81[8]
HPS	0.9	0.9	0.81
MH	0.9	0.7	0.63
HPS: High Pressure Sodium MH: Metal Halide			

[7] Use 0.9 or LM value provided by the Manufacturer at 60,000 hours, if L70 is greater than 100,000 hours

[8] If using an LM value provided by the Manufacturer, the Total LLF is equal to 0.9 x LM60,000hr

LUMINANCE AND ILLUMINANCE CALCULATIONS

Calculations should be done in AGi32, DIALux, Visual, or comparable software, and include the following calculation grids:

- ROADWAY LUMINANCE
  - A calculation grid is required for every lane of traffic and oriented in the direction of travel spaced 10' OC along each lane, with two points across each lane.
  - Every section of roadway where criteria changes requires a separate calculation grid.
- INTERSECTION ILLUMINANCE
  - Intersection calculations done using horizontal illuminance grids that include the whole intersection, as well as all crosswalks associated with the intersections. Calculation points placed in a 5'x5' grid.
- SIDEWALK ILLUMINANCE
  - Horizontal sidewalk illuminance grids placed on all sidewalks, spaced every 5'-10' OC along the sidewalk with two points across the sidewalk.
- LIGHT TRESPASS ILLUMINANCE
  - Light trespass grids located 5' past the edge of ROW, into private property. Light trespass grids placed 5' AFF, oriented toward the street with calculation points every 5'-10' OC.
  - Light trespass calculation grids separated based on adjacent land use. If the project goes from a residential area to a commercial area, a separate light trespass calculation grid required for each section of the project.
  - If a structure is within 5' from the property line, light trespass grid to be placed on the structure, 5' AFF.
  - Light trespass values should not exceed the following:
    - Single Family Residential, Multifamily Residential, Industrial and Open Space properties: **0.1FC MAXIMUM.**
      - If this criteria is not feasible with proper shielding and distribution, a variance may be considered to allow up to 0.2Fc Maximum light trespass in residential areas. Designer will be required to submit a narrative describing the efforts to control light trespass to the City Engineer.
    - Commercial, Restaurant/Retail/Civic, and Mixed-use Residential properties: **0.3FC MAXIMUM**
- CROSSWALK VERTICAL ILLUMINANCE
  - Vertical illuminance grids are required in all crosswalks at 5' AFF, and oriented toward oncoming traffic (See Figure 55). Calculation points should be located along the center line of each crosswalk, placed every 5' OC.

Designers submissions to the City should include a calculation summary table for each calculation grid and include the average illuminance or luminance, maximum illuminance or luminance, minimum illuminance or luminance, and Avg:Min ratio. Calculated values may vary from criteria by no more than 10% above or below.

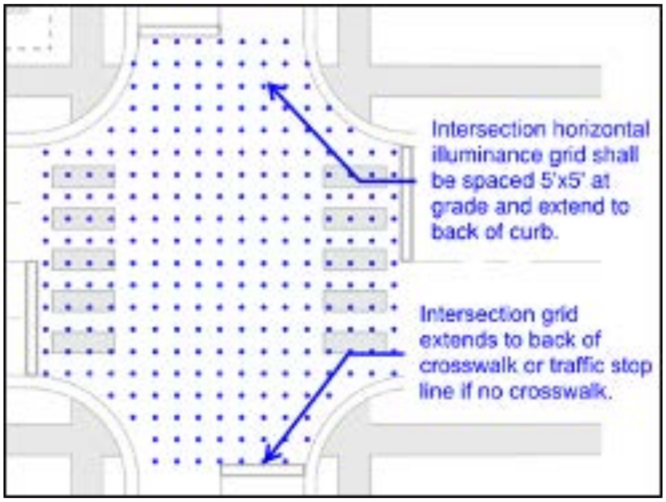

Figure 55: Horizontal Intersection Illuminance Grid

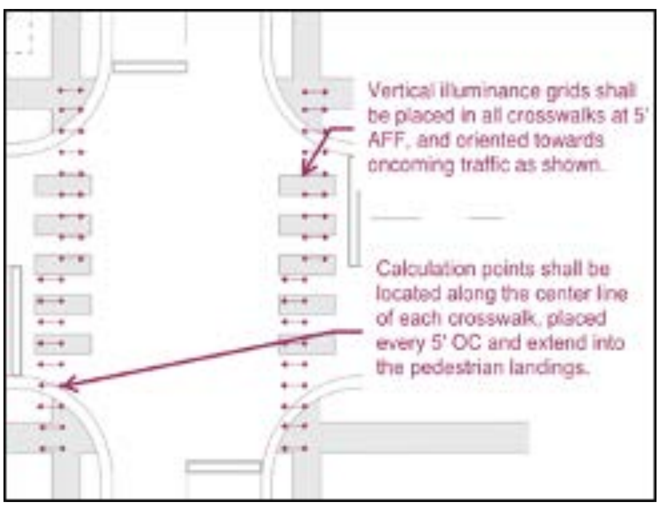

Figure 56: Vertical Intersection Illuminance Grid

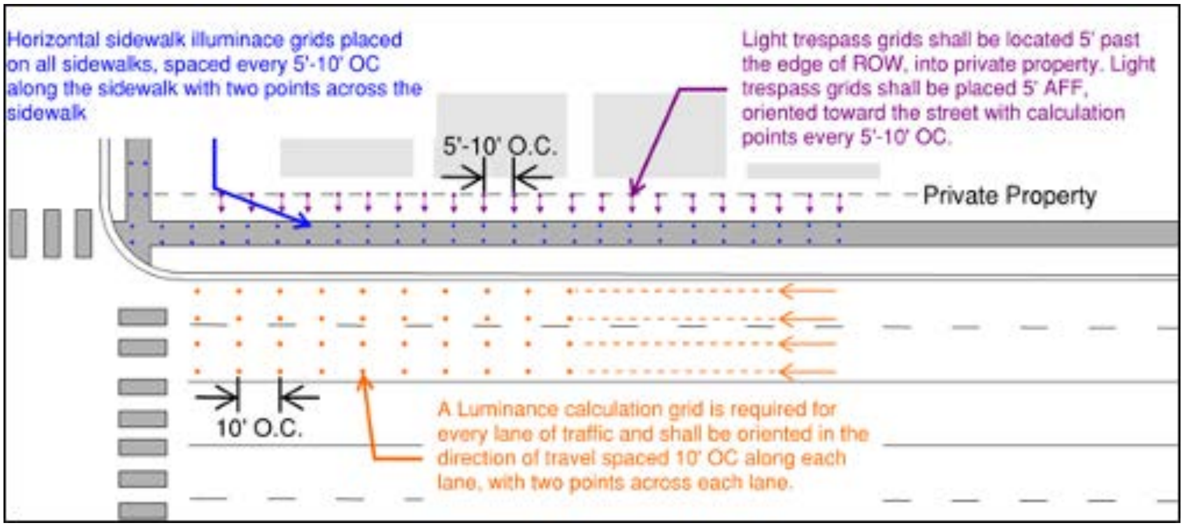

Figure 57: Roadway, Sidewalk, and Light Trespass Calculation Grid Setup