Clanton & Associates, Inc. WMS Field Lights Evaluation

Concerned WMS Neighbors, Arlington, Virginia

9/16/2016

About Clanton and Associates

Since 1981, Clanton & Associates has been designing visual environments, integrating daylight and electric light to enhance spaces, and designing light for indoor and outdoor environments with a strong commitment to environmental stewardship, minimizing energy use, sky glow and light trespass.

Nancy E. Clanton (PE, FIES, IALD, LC, LEED Fellow) is founder and president of Clanton & Associates. She obtained her Bachelor of Science degree (Architectural Engineering, Illumination Emphasis) from the University of Colorado, Boulder. She is currently a member of the National Academy of Sciences committee for the “Assessment of Solid State Lighting”, was awarded the Illuminating Engineering Society of North America (IESNA) Presidential Award in 1990 and 2006, the IESNA Distinguished Service Award in 2015, and the 2013 International Clean Design Award – Helsinki.

Ms. Clanton is a lifelong member and past member of the Board of Directors of the International Dark Sky Association (IDA), Past Chair of the Illuminating Engineering Society’s Board of Fellows and has served in leadership roles in numerous other professional societies concerned with lighting design. She co-chaired the joint IDA-IES committee that developed the Model Lighting Ordinance (MLO). She and her firm have worked extensively with communities nationwide to design quality and sustainable lighting systems.

Additional information about Ms. Clanton and her firm is attached at Appendix A.
**Scope of Work**

Nearby neighbors, whose property borders the Williamsburg Middle School soccer fields, asked Clanton & Associates to assess and comment on the light pollution, human health, environmental and energy-related impacts of the proposal to install lights on one or more of the soccer fields.

Clanton & Associates was also asked to evaluate questions and concerns raised in a May 10, 2016, memorandum (Appendix B) prepared by Mr. John Seymour, who serves on Arlington’s Environment and Energy Conservation Commission and the County Board-appointed Williamsburg Field Site Evaluation Work Group (WFWG) as well as Musco Lighting’s response to Mr. Seymour’s memorandum (Appendix C).

Clanton & Associates conducted the following analysis using materials available on the Williamsburg Field Site Evaluation Work Group website and other public sources, as well as background information provided by concerned neighbors.

**Major Conclusions**

Following are our major conclusions:

Installation of the proposed 5700K LED luminaires on 80’ poles, with a Class III designation is inappropriate for this neighborhood setting. It is our opinion that a decision to approve such lighting would:

- Exceed IES RP-6-15 lighting recommendations for recreational soccer fields (middle and elementary school setting with only a small seating space)
- Visually impact the nearest neighbors as a result of viewing the illuminated luminaires. Modeled glare (exceeds 2,500 cd on property line for Lighting Zone 1) per the International Commission
on Illumination (CIE) 150 E1 zone, and will be amplified by reflected light from the fields, and illuminated haze on high humidity evenings

- Increase human health and environmental risks based on evidence compiled and evaluated by the American Medical Association’s Council on Science and Public Health for LED street lighting. Lighting levels on sports fields are typically 20 to 30 times higher than street lighting levels; thus the AMA Council’s advice must be taken seriously when deciding to illuminate athletic fields close to residential homes.

- Class III lighting levels will use more energy than Class IV. The least amount of energy use would be no lighting.

- Violate Arlington County’s Zoning ordinance, limiting pole heights to 68’ above the average elevation of the school campus.

- Does not offer the opportunity to independently evaluate the lighting calculations provided by Musco Lighting with independent calculations since photometric data in “ies” format is not provided.

Our opinion is for the County to obtain the approval of a majority of the neighbors who will be most directly affected, as recommended in IES RP-33-14 “Lighting for Exterior Environments”. According to the concerned neighbors group, the overwhelming majority of neighbors who would be most directly affected by lights on the WMS soccer fields have signed a petition strongly opposing field lights. This joint statement of opposition is not limited to 5700K lights on 80’ poles – it extends to any type of athletic field lighting regardless of color temperature, placement, number or height of the luminaires and poles. (Appendix D)

**Background (Provided to Clanton & Associates by Concerned Neighbors Group):**

The neighborhood surrounding Williamsburg Middle School/Discovery Elementary School is unusually tranquil, even by the standards of a generally quiet and leafy North Arlington residential area. The neighborhood
is zoned R-10 and R-20, which allows only single family homes on a minimum of 10,000 to 20,000 square foot lots. The neighborhood contains no retail, commercial, or multi-family residential developments. It is, by any measure, a quiet and peaceful residential neighborhood.

The School property itself has historically hosted afternoon recreational soccer games, with elementary and middle school participants. The activity is wholly consistent with the residential nature of the setting, and has been conducted for decades without serious complaint or hindrance.

Consistent with long-established standards for aesthetic harmony within Arlington, the Williamsburg campus (zoned S-3A) is subject to a 68 foot height limitation measured from the average elevation of the school property. Because the soccer fields sit on an elevated portion of the Williamsburg School property, the zoning limitation will place severe restraints on the height of any structure there. Such restrictions are, in our view, particularly appropriate here because the light poles proposed by Musco will not only represent (if constructed) a major variance in Arlington’s height limits, but add highly intrusive and glare-producing light. Together — the high poles and the very bright LED lights — likely will transform the overall ambience of the setting from dark, quiet and tranquil to bright, active, and quasi-urban.

It should be emphasized that residences are located much closer to fields than is typically the case for lighted sports fields. At Williamsburg, the nearest property lines are located only 25-35 yards from the nearest goal lines. Absent a showing of extraordinary need, fields being designed and constructed today for nighttime athletic use would not be placed in such a setting.

During the 2012-2103 public process required for consideration of a Use Permit for the design and construction of the Discovery Elementary School, neighbors were repeatedly assured that the soccer fields on the property would not be lighted. Rather, the fields were to be preserved as natural grass fields and no field lights would be installed. Only following the July 2013, completion of this public process did the County Manager’s office propose to install synthetic turf with an expedited process to install field
lights. Following the vocal opposition of neighbors and the affected civic association, the County Board deferred its decision on field lights pending review by the Williamsburg Lights Working Group. Consistently, and to date, the neighbors most directly affected have strongly opposed the lighting of the athletic fields as does the civic association that represents them.

This history is important because the effects of lights are felt through level of trust neighbors’ have in the transparency and fairness of the decision process as well as the objective harm they experience. Here, it is proposed that athletic fields in an historically dark setting would be lighted for the first time in its history. The intrusion of multiple high poles radiating light levels 20-30 times higher than existing street lights, the flawed 2012-2013 administrative process and the subsequent time-consuming multi-year effort required to preserve neighbors’ quality of life, would combine to magnify the negative effects of the lights.

The Williamsburg Fields

From a review of the materials provided to us, it is clear that the site is difficult to light to minimize light trespass and glare because of the short distance between the fields and the houses adjacent the fields.

Below are assumptions used in our opinions:

- The light trespass spill light recommendations applicable to the soccer fields in this neighborhood are 1 lux (0.1 footcandles) for Lighting Zone 1 per RP-33-14 typical for single family residential neighborhood.
- The light trespass glare at the property line shall be no greater than 2,500 candela for pre-curfew and 0 candela for post curfew hours per CIE 150 “Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Lighting Installations” E1 zone (LZ1 – RP-33-14)
The lights under consideration — 5700 Kelvin sports lighting — produce a light spectrum that has been associated with a variety of human health and environmental concerns.

The fields should be classified as Class IV recreational fields using standards of the IESNA, “Sports and Recreational Area Lighting” RP-6-15. Such fields are those for competition or recreational play with no or limited provision for spectators and are generally lighted to provide a horizontal illuminance of 200 lux (20 footcandles).

It is our opinion that the fields should not be lighted without neighborhood consensus, and criteria compliance independently verified and calculated with photometric data supplied by Musco Lighting.

1. **Light trespass (illuminance) and glare (luminous intensity – candela and/or luminance – candela/meter²):** Light trespass (illuminance) is a measure of vertical and horizontal illuminance falling on points along the property line. As acknowledged recently by nearby Fairfax County, “when light crosses property lines it can detract from the property value and quality of life of those whose property it is improperly directed towards. It can be particularly objectionable problem when obtrusive recreational lighting is immediately adjacent to residential neighborhoods.” Fairfax County, Athletic Field Lighting and Control of Obtrusive Light Pollution (July 2010). Glare, in contrast, is generally understood as excessive brightness occurring in the normal field of view in units of maximum candela (photometric data) or candela per meter² (luminance). Thus, the same light source can produce both glare and light spill, but the perception depends on whether the light enters the eye directly or reflects off of objects in the field of view.

A significant feature of both light spill and glare is that they are both influenced heavily by ambient conditions. As Fairfax County noted, “glare experienced from high-intensity sources, like those used to light athletic fields, is the result of the source-to-background contrast ratio.” Similarly, researchers have concluded that ambient conditions have a significant effect on how light trespass is perceived. The International Commission on Illumination, in its “Guide on the Limitation of the Effects of Obtrusive Light
from Outdoor Lighting Installations” has cautioned that the “tolerable levels” of light spill and glare “will be influenced by the ambient lighting existing in that environment,” which, in turn, is the product of “the degree and type of the development of the area and by the lighting in place.”

As we understand from the materials provided to us, the property affected by light is “historically dark residential,” the fields have never been lighted in their decades of use, and ambient levels of light at the western residential property line are low as measured by neighbors.

As with all of the data provided to us, we are not in a position to check the calculations because the vendor has not provided the photometric data. Nevertheless, Musco’s modeled levels show that glare levels (candela) as currently projected are higher than recommended for sites such as the Williamsburg fields. The CIE has developed a widely accepted set of targets for maximum intensity of luminaries (glare) in different “environmental lighting zones.” For lighting environments that are “intrinsically dark” (Lighting Zone E-1), the CIE Technical Report 150 has established a maximum glare measure of 2500 candela at property lines. The Illuminating Engineering Society of North American (IESNA), in its recommended practice guide “Lighting for Exterior Environments” has endorsed the CIE model. It noted that Zone E1 is appropriate for “areas with intrinsically dark landscapes”, including “residential areas where inhabitants have expressed a strong desire that all light trespass be strictly limited.” According to IES RP-33-14. That description aptly describes the Williamsburg site.

Significantly, the levels of glare (worst-case aimed fixture) modeled by Musco under its best-case scenario (80’ poles) greatly exceed the maximum 2,500 candela threshold. Music’s data for 80’ poles provided on April 14, 2016 show a maximum of 6,460 candela at the property line - more than twice the recommended maximum. There is an additional value of 20,677 candela close to a property line adjacent to Pole S3. The glare values along this property line have not been provided. It is our opinion that the 2,500 candela threshold is necessary here, in light of the historical darkness of the setting, the close proximity of residences, and the neighbors’ strongly-expressed sensitivity and opposition to light trespass and glare.
We note, in addition, that the modeling does not include glare produced through reflected light from other surfaces, or from water-vapor in the ambient air during Arlington’s numerous humid spring and summer nights. Thus, total glare is likely to be greater than modeled.

In addition, some of the calculations are incomplete, including glare angles for players, and do not provide all of the information necessary to confirm compliance with generally accepted standards for glare and light trespass. Without full access to the photometric data, an independent review of the calculations cannot be done. However, from the available information provided by Musco, it appears that glare will be excessive.

**Sky Glow:** As noted above, we have been advised that the Williamsburg neighborhood is quite dark and that, even on the existing Williamsburg sports fields themselves, residents state that the stars are clearly visible. The lights proposed to date will clearly increase sky glow — visible light reflected by particiles in the atmosphere, which deprive residents of the opportunity to “see the night sky as their ancestors did, star-gaze and relax under a beautiful natural night sky.” IES RP-33-14.

Because higher correlated color temperature (CCT) light sources have more blue light, their impact on sky glow is greater.

The lights at issue will affect sky glow both directly — by emitting light from the source itself — and by casting light upwards from the surface being illuminated (reflected light). Although we do understand that the luminaries are designed to reduce sky glow and the colored synthetic surface will absorb some of the light, some increase in sky glow is inevitable.

A paper prepared by Ian Ashdown, “Color Temperature and Outdoor Lighting,” (2015) raised concerns about the adverse effects of high temperature Kelvin LED lights on sky glow, and endorsed the recommendation of the International Dark Sky Association to require a maximum of 3,000 Kelvin for luminaries to receive the IDA’s Seal of Approval. Mr. Ashdown concluded that blue light is preferentially scattered and thus caused greater sky glow. In particular, Mr. Ashdown endorsed the finding of the IDA that “the case against blue light is well founded with
regard to discomfort glare, circadian rhythm disruption, light scattering, sky glow, and biological disruption in wildlife.”

In response to this concern, Musco Lighting noted that Mr. Ashdown published an update of his findings, in which he concluded that the spectral distribution from light reflected from a Kentucky bluegrass sports field alleviates “the nightmare spectrum” problem to some extent. In that same update, however, Mr. Ashdown commented that “light pollution” near outdoor athletic fields can nevertheless be “a significant concern for residential neighborhoods.” Significantly, Mr. Ashdown’s piece and Musco’s response continue to highlight the importance of reflected illuminance, whether from the fields themselves or from surrounding structures.

**Human Health and Environmental Effects:** We understand that the Working Group has submitted considerable documentation to the County setting forth the evidence demonstrating real health and environmental concerns associated with the types of LED lights being proposed for the Williamsburg site. We will not repeat that evidence here, but refer the reader to the very recent AMA report entitled “Human and Environmental Effects of Light Emitting Diode Community Lighting.” Among other findings, the report cautions that “much has been learned over the past decade about the potential adverse health effects of electric light exposure, particularly at night. The core concern is disruption of circadian rhythmicity. With waning ambient light, and in the absence of electric lighting, humans begin the transition to nighttime physiology about dusk; melatonin blood concentrations rise, body temperature drops, and sleepiness grows.” High correlated color temperature LED lighting of the kind proposed at the Williamsburg site has been found to have a disproportionate adverse effect on circadian rhythm, as well as other adverse health effects.

The responses prepared by the County and the contractor to date do not, in our view, fully address these concerns. Musco Lighting states simply that there is “lots of hype being made about something that might exist” and that more research is needed. Thus, the contractor looks to the medical community to resolve the issue. The County’s medical authority, on the other hand, looks to Musco Lighting to address it — asserting that the medical risks should be minor if Musco Lighting can control light efficiently. Only an independent review can verify this. Nevertheless, we note that
lighting levels from sports facilities are typically 20 to 30 times higher than the street lighting of concern to the AMA.

We must also note that all of the data provided to date are calculated, rather than measured. We do not have access to the photometric data, or the algorithms, assumptions, and spectral distributions underlying the calculations. Thus, we are in no position to check or confirm the calculations. At the very least, however, we strongly recommend that an independent evaluation be performed for illuminance, light trespass, glare (maximum candela), and sky glow calculations arising from the proposed design so that the neighbors, and the County, have a full understanding of the issue.

**Clanton & Associates Opinions**

- The WMS soccer fields are Class IV fields
- The neighborhood residential properties are classified as Lighting Zone 1 per IES RP-33-14, which is consistent with Arlington County’s established R-10 and R-20 zoning of the affected neighborhood.
- Light trespass should not exceed Lighting Zone 1 restrictions per IES RP-33-14 and Environmental Zone E1 per CIE150:2003.
- Any field lighting project should be consistent with recommendations from the Illuminating Engineering Society (IES), International Commission on Illumination (CIE) and International Dark Sky Association (IDA).
- Short wavelength (blue) light, similar to 5700K LED lights will increase sky glow. Indeed, any field lighting will increase sky glow.
- Glare and light trespass must be restricted so as to minimize or eliminate direct view of the lighted luminaire on neighboring properties per CIE 150:2003. Specifically, glare should not exceed 2,500 candela and light trespass should not exceed 0.1 footcandles.
- Blue light wavelengths suppresses melatonin and should be minimized or avoided.
- The calculations provided by Musco Lighting do not meet all of the recommended requirements and recommendations.
- Since photometric tests are not available, independent calculations of glare (maximum candela or luminance), light trespass, reflected light, sky glow prediction and spectral distribution are not feasible.

**Conclusion:** As set forth above, we have examined whether the “impacts, for the first time, of lighting one or two fields at Williamsburg can be mitigated sufficiently to protect the character of the neighborhood and provide a reasonable quality of life to the nearest neighbors.” It is our opinion that the proposed sports field lighting does not achieve that goal.
CURRICULUM VITAE

Nancy Clanton, PE, FIES, IALD, LC, LEED Fellow
President
Clanton & Associates, Inc.

Nancy E. Clanton is founder and President of Clanton & Associates, a lighting design firm specializing and leaders in sustainable design since 1981. She obtained her Bachelor of Science degree (Architectural Engineering, Illumination Emphasis) from the University of Colorado, Boulder and is a registered Professional Engineer in the states of Colorado and Oregon. Nancy is currently a member of the National Academy of Science committee for the “Assessment of Solid State Lighting”. Nancy led the lighting workshops for the C40 conference in Seoul, was awarded the IESNA Presidential Award in 1990 and 2006, the IESNA Distinguished Service Award in 2015, the 2013 Outstanding Woman Engineer of the Year for the American Council of Engineering Companies – Colorado, and the International 2013 CleanDesign Award – Helsinki, and National Institute of Building Science Honor Award for contributions to the Low Vision Design Committee.

Nancy has been deeply involved in promoting quality daylighting and sustainable electric lighting design. As lighting group leader for Greening of the White House, Grand Canyon and Pentagon, these monumental recommendations helped shape and form sustainable design. In addition, Nancy participated in the 2004 AIA Sustainable Design conference series broadcast to all AIA chapters.

Nancy has served with the IALD in the following positions:

- IALD representative for founding NCQLP 1991
- IALD Director of Marketing and External Affairs 1999 – 2000
- IALD Director of Marketing and Communication 2001 - 2002
- IALD Executive Search Committee 2002
- IALD Ethics Committee 2002
- IALD Director of Finance 2003 – 2004
- IALD LightFair Committee 2005
- IALD Education Conference 2006
- IALD ACE conference speaker 2010, 2011
- IALD Enlighten Americas speaker (multiple years)
- IALD LightFair speaker (multiple years)

Nancy and her firm’s team authored the California Energy Code Title 24 Exterior Lighting sections.

Nancy has been involved in lighting visibility research that has helped determine quality visibility metrics for streetlighting. Nancy has also been extremely active in lighting technical societies as chair of key application committees and co-author of recommended practices and technical memorandums used in LEED and sustainable design.
Her firm’s lighting design projects reflect her sustainable philosophy with ten projects achieving LEED Platinum including the USGC HQ, Empire State Building and Rocky Mountain Institute Boulder HQ, the US Embassy in Helsinki and eleven of their projects have been named to the AIA Committee on the Environment Earth Day Top Ten List.

As an educator, Nancy has been honored to be a Master Speaker for GreenBuild 2004 the “Best of Greenbuild” for GreenBuild 2006. She has also taught numerous sustainable lighting design classes for universities, utility energy centers, professional associations, governmental agencies and city and state agencies. In addition, Nancy has been a speaker at multiple national and international conferences.

In Nancy is past member of the LEED Environmental Quality Technical Advisory Group, providing lighting control, daylighting and views expertise. Nancy received the “USGBC Above and Beyond” 2013 Volunteer Award. Clanton & Associates, Inc. projects have obtained 13 Platinum, 7 Gold, 9 Silver and 2 Certified Certifications.

Nancy is a member of the National Institute of Building Science (NIBS) Low Vision Design Committee developing design standards for the visually impaired. In addition, Nancy is a founding member of the AIA/NIBS BRIK committee on the collection of building science research.

Nancy is a voting member of the International Standards Organization (ISO) technical advisory group ISO/TC 205 for Building Environmental Design.

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**LEED Certified Project Clanton Team Experience**

**Platinum Rating:**

**US Embassy Innovation Center (pending)**  
Helsinki, Finland  
First 100% Solid State Lighting embassy

**US Green Building Council Office Building**  
Washington, DC  
Commercial Interiors  
First project certified in LEED v3

**Empire State Building**  
42nd Floor Prebuilt Space  
Commercial Interiors

**Paisano Green Community**  
El Paso, Texas  
New Construction  
First Net Zero, LEED Platinum public senior housing community in the USA
Democracy Now!
New York, New York
*Commercial Interiors*
*First radio or television studio certified for CI*

**Business Instructional Facility**
University of Illinois – Urbana/Champaign
Champaign, Illinois
*New Construction*

**Audubon Center**
DEBS Park
Los Angeles, California
*New Construction*

**Rocky Mountain Institute/ENSAR**
Boulder, Colorado
*Commercial Interiors*

**Rocky Mountain Institute Boulder HQ**
Boulder, Colorado
*Commercial Interiors*

**Lewis and Clark State Office Building**
Jefferson City, Missouri
*New Construction*

**Las Vegas Living Center and Gardens**
Las Vegas, Colorado
*New Construction*

**Hannaford Store**
Augusta, Maine
*New Construction*
*First grocery store certified platinum*

**Tah.Mah.Lau Residence**
Portola Valley, CA
*Homes*

**Enermodal Engineering Office**
Denver, Colorado
*Commercial Interiors*

**Gold Rating:**

**Empire State Building**
*Existing Buildings*

**Doerr Hosier Center (Aspen Institute)**
Aspen, Colorado
New Construction

**Viceroy Snowmass Resort**
Snowmass Village, Colorado
*New Construction*

**Fred M. Rogers Center**
St. Vincent College
Latrobe, Pennsylvania
*New Construction*

**University of Denver College of Law**
Denver, Colorado
*New Construction*

**University of Texas School of Nursing**
Houston, Texas
*New Construction*

**Brasada Ranch House**
Brasada Ranch Resort
Powell Butte, Oregon
*New Construction*

**Silver Rating:**

**Fossil Ridge High School**
Fort Collins, Colorado
*New Construction*

**Block 21**
Austin, Texas
*New Construction*

**Tom Ridge Environmental Center**
At Presque Isle
Erie, Pennsylvania
*New Construction*

**Thomas Bradley International Terminal**
Los Angeles International Airport
Los Angeles, California
*New Construction*

**Snowmass Clubhouse**
Aspen, Colorado
*New Construction*

**Nidus Center for Scientific Enterprise**
Monsanto Campus
Creve Coeur, Missouri
New Construction

**Colorado State Capitol Building**
Denver, Colorado
*Existing Buildings: Operations and Maintenance*
*First project certified in this category*

**Denver Justice Center Office Parking Garage**
Denver, Colorado
*New Construction*

**Washington State Penitentiary**
Walla Walla, Washington
*New Construction*

**Certified:**

**Stop & Shop Store**
Foxboro, Massachusetts
*New Construction*

**IHM Motherhouse**
Monroe, Michigan

**Research and Publications**

- IES RP-33-99 and IES RP-33-13 “Recommended Practice on Lighting for the Exterior Environment” (lead author) which received a LightFair International 2015 Innovation Award
- IES TM-12 “Spectral Effects at Mesopic Lighting Levels” (co-author)
- IES Lighting 9th Edition Handbook (topic editor)
- California Energy Commission and New Buildings Institute – Advanced Lighting Guidelines (topic editor)
- IDA/IES Model Lighting Ordinance (MLO) (co-author)
- Department of Defense Lighting Criteria Unified Facilities Criteria (co-author)
- US Department of State Oversea Buildings Operation lighting guidelines review (co-author)
- Colorado Department of Transportation Lighting Design Guide (co-author)
- California’s Title 24 2008 energy code exterior sections (co-author)
- “Tale of Three Cities: Applying LED Streetlighting Technology” presented at the IES Annual Conference in Austin, TX - October 31, 2011 (co-author)
- “Advanced Street Lighting Technologies Assessment Project – City of San Jose” – August 6, 2010 (co-author)
- “Street Lighting Survey for Commercial Areas in the Municipality of Anchorage” – October 2, 2009
- Alternative Lighting Evaluations: Municipality of Anchorage. Poster Presentation at the Transportation Research Board Annual Meeting, Washington DC. Gibbons, R., Clanton, N., Edwards, C., and Mutmansky, M. (2010). This is the first in-situ analysis of alternative lighting system performance to incorporate both illuminance and human performance measures. This analysis has led to the on-going assessments of alternative sources in several other locations.
Nancy Clanton – CV

- Building Standards Magazine – article “Daylighting and Night Darkening”; March-April 2002

Professional Registration

- Registered Professional Engineer, Colorado
- Registered Professional Engineer, Oregon

Certifications

- LEED Fellow, November, 2012
- LEED AP BD+C, January 4, 2011
- LEED 2.0 Accredited Professional, September 2, 2003
- NCQLP Lighting Certified (LC)

Education

- Bachelor of Science, Architectural Engineering, University of Colorado, 1975

Professional Affiliations

- National Academy of Science, Member of Solid State Lighting Assessment Committee
- LEED EQ Technical Advisory Group past member
- AIA/NIBS BRIK founding steering committee member
- CIE Indoor visual environment (ISO TC 205/WG 7) - TAG member
- American Institute of Architects and National Institute of Building Science, founding member of the steering committee for the Building Research Information Knowledgebase
- University of Colorado Professional Advisory Board Member for Department of Civil, Architectural Engineering and Building Sciences
- Illuminating Engineering Society (IES) Fellow, Sustainable Member, and Distinguished Service Award
- International Association of Lighting Designers Professional Member and past Board of Directors Member
- International Dark Sky Association Lifelong Member and past Board of Directors Member
- Rocky Mountain Institute, Fellow
- National Society of Professional Engineers Member
- Professional Engineers of Colorado Member
- USGBC- Colorado Chapter member
- Clinton Climate Initiative Technical Resources Group
- IES Board of Fellows past Chair
- IES Lighting for Outdoor Public Spaces Chair
- IES Mesopic Committee Chair
- IES Outdoor Environmental Committee Past Chair
- IES/IDA Model Lighting Ordinance Task Force Chair
- IES Lighting Criteria Committee Member
- NIBS “Lighting for Low Vision” committee member

Honors

- IES Distinguished Service Award 2015
- International 2013 CleanDesign Award
- Association of Engineering Companies – Colorado 2013 Outstanding Woman Engineer of the Year
- International Dark Sky Association – 2013 Dark Sky Defender Award for Research and Training
- USGBC LEED Fellow
- UGGBC “USGBC Above and Beyond” 2013 Volunteer Award
- IES Presidential Award 1990
- IES Presidential Award 2006
- IES Fellow
- Rocky Mountain Institute Fellow
- Clinton Climate Institute Lighting Leader – C40 Seoul Conference
- National Academy of Science Assessment of Solid State Lighting Committee Member
- AIA Colorado Northern Chapter Northern Chapter Contribution to the Built Environment Award 1999

**USGBC Seminars**
- USGBC - “Understanding the May Addendum & Achieving Success in Daylighting”
  Webinar - July 21, 2011
- Greenbuild 2006 - Best of Greenbuild - “Best Architectural Practices”
  Denver, CO - November 15, 2006
- Greenbuild 2004 - “Lighting Design - Master Speaker”
  Portland, OR - November 11, 2004
- USGBC Colorado - Fall Conference - “Exterior Lighting Design”
  Denver, CO - September 25, 2004

**Teaching Experience (day long or multi-day workshops and courses)**
- Colorado Department of Transportation - Roadway Lighting Design Training
  Denver, CO – October 16 – 17, 2013 and March 31 – April 2, 2015
- Colorado State University – Denver - Green Building Certificate Program
  Denver, CO - October 20, 2009; Fort Collins, CO – April 16, 2009
- California Lighting Technology Center - UC Davis
  “Outdoor Lighting Symposium – Organizer, facilitator and speaker”
  Davis, CA - September 9-10, 2008
- Wisconsin Energy Center - “Lighting and Daylighting: Beyond Footcandles” Appleton, WI, September 26, 2012
- Wisconsin Energy Center - “Lighting and Daylighting: Beyond Footcandles”
  Appleton, WI – September 25, 2012
- Wisconsin Energy Center - “Lighting and Daylighting: Beyond Footcandles”
  Des Moines Area Community College Ankeny campus – April 26, 2012
- Wisconsin Energy Center - “Lighting and Daylighting: Beyond Footcandles”
  Chicago, IL - June 2, 2011
- Pacific Gas and Electric (PG&E) – Energy Center - “Energy Efficient Lighting”
  San Francisco, CA - March 4, 2003; November 5, 2002
- Pacific Gas and Electric (PG&E) - Energy Center - “Advanced Lighting Workshop”
  San Francisco, CA
  September 6, 2001
- Pacific Gas and Electric (PG&E) - Energy Center - “Optimizing Opportunities in Outdoor Lighting”
(with Jim Benya)
San Diego, CA - October 14, 1998

- Southern California Edison - “School Classroom Lighting (LAUSD)”
  Los Angeles, CA - October 6, 2004

- Sacramento Municipal Utility District (SMUD) - Energy & Technology Center - “Lighting and Dark Sky”
  Sacramento, CA - June 29, 2004

- Sacramento Municipal Utility District (SMUD) - Energy & Technology Center - “Outdoor Lighting – Changes on the Horizon”
  Sacramento, CA - July 17, 2002

- Sacramento Municipal Utility District (SMUD) - Energy & Technology Center - “Lighting for Architects”
  Sacramento, CA - September 7, 2001

- Colorado Department of Transportation - Roadway Lighting Training

- State of Wyoming - “Lighting for Educational Facilities”
  Cheyenne, WY - May 3, 2006; Casper, WY – May 2, 2006; Cheyenne, WY – November 18, 2004

- State of Pennsylvania - “Lighting for Correctional Institutions”
  Harrisburg, PA - July 9, 2002

- City of Austin - 1998 Texas Sustainable Building Professional Training Seminar - “Integrated Design Process” (with Bob Berkebile)
  Austin, Texas - February 18, 1998

- International Dark Sky Association - “Model Lighting Ordinance Training”
  Seattle, WA - October 26, 2011

- Environmentally Sustainable Architecture - Workshops on profitable, healthy, productive buildings with low environmental impact - “Architectural Lighting Design Concepts, Systems and Controls”
  (with Greg Franta and Kristine Anstead)

- Fort Collins March 17-18, 1995; Carbondale April 21-22, 1995; Colorado Springs April 28-29, 1995;
  Denver May 19-20, 1995

- Federal Energy Management Program (FEMP) - “Lighting for Health, Human Performance, Energy and the Environment (taught with Dr. Joan Roberts and Lisa Heschong)
  San Francisco, CA - September 28, 2005; Philadelphia, PA- November 4, 2004; Fort Worth, TX – November 2003

- US Department of Health and Human Services and FEMP Lights – Lighting and Health Workshop
  “Energy Effective Lighting, Lighting as if People Mattered” and “New Directions: Lighting Policies, Standards Initiatives” (taught with Dr. Joan Roberts and Lisa Heschong)
  Washington, DC - April 30, 2003

- Federal Energy Management Program (FEMP) – Facility Solutions Group Design Center - “Advanced Lighting Workshop (FEMP)”
  Dallas, TX - April 10-12, 2002; San Francisco, CA June 27-29, 2001; Golden, CO – November 15-17, 2000

- EFACHES - United States Air Force - “Lighting Criteria”
  Washington, DC - August 14, 2002

- Naval Facilities Engineering Service Center - Antiterrorism Team - “Security Lighting Training”
  California - July 15-17, 2007

- Alaska Center for Appropriate Technology at University of Alaska – Anchorage
  “Lighting Design … Alaska Style!”
  Anchorage, AK - October 15, 2010 and Wasilla, AK – October 14, 2010

- American Society of Interior Designer (ASID) - “Lighting Design for Interior Designers”
Washington, DC - May 8, 2002

- IES Lighting Courses – continuing education for professional engineers and architects
  Denver, CO - 1981

- University of Colorado – School of Engineering – Instructor – Illumination I and Electrical Systems for Buildings
  Boulder, CO – 1978 - 1986

Presentations

- USGBC GreenBuild 2015 – “Smart Cities Start with Smart Streetlighting”
  Washington D.C. – November 18, 2015

- IES Street and Area Lighting conference 2015 – “New Standards for a New Era”
  Savannah, GA – October 4, 2015

- American Planning Association Colorado State Conference 2015 – “Smart Cities Start with Smart Streetlighting”
  Steamboat Springs, CO – September 30, 2015

- Stamats Communications for Buildings Magazine webinar – “Transformation of Outdoor Lighting”
  Boulder, CO – September 24, 2015

- NavFac Improved Lighting Technology Conference – “Light and Health”
  Virginia Beach, VA – September 17, 2015

- National Park Service Natural Sounds and Night Skies Division conference – “State of Current Lighting Technology, Controls, Fixture Technology” – panel discussion
  Fort Collins, CO – September 25, 2015

- Clean Tech Energy Fellows Institute – “Smart Building Technology – Lighting”
  Boulder, CO – June 11, 2015

- 3rd International Conference on Artificial Light At Night Conference (ALAN 2015) – “Assessing than Mitigating (Skyglow Measurements to Lighting Ordinances)” and “Plenary Session IV – Chairman”
  Sherbrooke, Quebec, Canada – May 30, 2015

- American Institute of Architects Annual Conference – “Designing Supportive Environments for People with Low Vision”
  Atlanta, GA – May 15, 2015

- LightFair International – “Urban Lighting Installations: Human Scale to Big Data”
  New York, NY – May 6, 2015

- Stanford University lecture – “Daylighting and Electric Lighting Design”
  Palo Alto, CA – April 30, 2015

- University of Colorado – Senior Engineering Seminar
  Boulder, CO – April 20, 2015

- Transportation Symposium of Colorado – “Smart Cities Start with Smart Streetlighting”
  Denver, CO – April 10, 2015

- Workplace Benchmarking Conference 2015 – “Healthy Daylight Healthy Darkness”
  Washington DC – February 25, 2015

- Department of Energy Conference on Solid State Lighting Research “OLED Applications”
  San Francisco, CA – January 29, 2015

- IALD Enlighten Conference “Light and Human Behavior in the Exterior Environment”
  San Diego, CA – October 19, 2014

- ALAN 2014 Conference “Successful Dark Sky Applications”
  Leicester, UK – September 4, 2014

- E Source Leadership Conference – “Filling the Lighting Void”
  Boulder, CO – September 29, 2014
Nancy Clanton – CV

- International “How to Choose a LED Luminaire that Performs as Good as it Looks”
  Las Vegas, NV – June 4, 2014
  Cleveland, Ohio – April 6 – 8, 2014
- Colorado City & County Management Association (CCCMA) Winter Conference – “Shining a Bit of Light on Street Lighting”
  Glenwood Springs, CO – February 20, 2014
- NIBS Low Vision Design Committee (LVDC) Symposium “Creating Flexible Environments for people with Low Vision, Adaptable and Flexible Lighting Design”
  Washington DC – January 9, 2014
- Lahti CleanDesign Forum – “Lighting Design in Everyday Surroundings”
  CleanDesign Center, Lahti, Finland – November 21, 2013
- Corporate CleanTech Venture Day Conference – “The New Era of Sustainable Lighting – Street Lighting” keynote and panel discussion
  Lahti, Finland – November 20, 2013
  US Embassy, Helsinki, Finland – November 19, 2013
- Startup Sauna – “Diversity – The Perfect Balance for Innovative Creativity”
  Aalto University campus Otaniemi, Betonimiehenkuja 3D, Finland – November 19, 2013
- International Dark Sky Association – “Tale of Four Cities”
  Tucson, AZ – November 15, 2013
- Association of Light at Night (ALAN) – “Tale of Four Cities”
  Webinar to conference attendees in Berlin, Germany – October 29, 2013
- IALD Enlighten – “Developing Leadership: Mentoring in a Dynamic Profession”
  Montreal, Canada – October 4, 2013
- E Source Conference – “Big Savings with LED and Lighting Controls”
  Denver, CO – September 19, 2013
- Street and Area Lighting Conference – “Seattle Streetlighting Research Results”
  Phoenix, AZ – September 10, 2013
  Helsinki, Finland – June 6, 2013
  Helsinki, Finland – June 6, 2013
  Helsinki, Finland – June 6, 2013
- CED – “Checklist for LED Applications”
  Denver, CO – May 15, 2013
- LightFair International – “Exterior Lighting Controls”
  Philadelphia, PA – April 24, 2013
  Philadelphia, PA – April 25, 2013
- Stanford University – “Sustainable Lighting Design”
  Palo Alto, CA – April 17, 2013
- MSSLC Webinar – “Exterior Lighting Controls - Real Experience”
  Boulder, CO – April 11, 2013
IES Webinar at the University of Colorado – “The Model Lighting Ordinance and TM-15”
Boulder, CO – April 2, 2013


IES Roadway Lighting Committee – Seattle Research Update – Dallas, TX – March 14, 2013

Greening the Military – “Strategies for Integrated Sustainable Lighting Systems and DOD Lighting Criteria” – Virginia Beach, VA – February 27, 2013


ACE – “Healthy Daylight, Healthy Darkness”
Mumbai, India – October 19, 2012

American Society of Landscape Architects – “LED Lighting: Lighting Designer Perspective” – Phoenix, AZ – October 1, 2012

E Source – “LED – Is Power Quality an Issue?”
Denver, CO – October 4, 2012

IES Street and Area Lighting Conference – “Induction – The Other Long-lasting White Light Source”
Miami, FL – September 10, 2012

LED Magazine Webinar – “Outdoor Lighting Design with LEDs”
Boulder, CO – August 20, 2012

DOE PNNL TINSSL Webinar – “Preliminary Results: Visual Quality, Acuity, and Community Acceptance of LED Streetlight Sources”
Boulder, CO – August 9, 2012

DOE Municipal Street Solid-State Lighting Committee – “NEEA Seattle Street Lighting Demonstration Project Update”
Boulder, CO – July 12, 2012

Stanford University – “Sustainable Lighting Design”
Palo Alto, CA – May 16, 2012

LightFair International – “Through the Eyes of the Beholder – Using POE’s to Guide Our Way”
Las Vegas, NV – May 9, 2012

Illuminating Engineering Society Maine Chapter – “Model Lighting Ordinance” – April 14, 2012

ACE and IALD International Conference - “Adding New Dimensions to Lighting Design”
Mumbai, India – November 4, 2011

Meeting of the Minds Conference 2011 - “Lighting Technology”
Boulder, CO
September 21, 2011

DOE Municipal Solid State Street Lighting Consortium - “City of San Jose LED Street Lighting Program” and “LED Streetlights and the Environment”
San Jose, CA - August 25, 2011

United States Army Corps Engineers (USACE) - “Lighting Criteria”
Atlanta, GA - June 15, 2011

Pacific Gas and Electric (PG&E) and IES San Francisco Section - “A Tale of Three Cities: The Quest for Energy Efficient Street Lighting”
San Francisco, CA - May 19, 2011

LightFair International - “Model Lighting Ordinance – Finally!”
Philadelphia, PA
May 18, 2011

- **LightFair International** - “Tale of Three Cities: Applying LED in a Roadway Environment”
  Philadelphia, PA - May 17, 2011

- **International Dark Sky Association** - “Model Lighting Ordinance (MLO) Update”
  Newark, NJ - April 17, 2011

- **Building News VIP Webinar** - “Transformation of Outdoor Lighting”
  Webinar - March 8, 2011

- **Canadian Street Lighting Summit** - “Best practices for Street Lighting Design: Implementing the latest research and standards”
  Toronto, ON - March 8, 2011

- **Strategies in Light** - “Solid State Lighting Lessons Learned, Successes and Opportunities”
  Santa Clara, CA - February 23, 2011

- **Architectural Green Lighting** - “Exterior Lighting”
  Berkeley, CA - January 27, 2011

- **Bioneers** - “Lighting … Alaska Style!”
  Anchorage, AK - October 16, 2010

- **Illumination Engineering Society** - “Model Lighting Ordinance”
  Webinar - October 13, 2010

- **International Association of Lighting Designers** - “The Lighting Designers Hippocratic Oath”
  Westminster, CO - September 9, 2010

- **International Association of Lighting Designers** - “Lighting Regulations: Good, Bad and Ugly”
  Westminster, CO - September 8, 2010

- **Street and Area Lighting Conference** - “IESNA Update”
  Huntington Beach, CA - September 29, 2010

- **Street and Area Lighting Conference** - “A Tale of Three Cities”
  Huntington Beach, CA - September 29, 2010

- **California Institute of Technology** - “Exterior Lighting”
  Pasadena, CA - September 16, 2010

- **GovEnergy** - “The Quest for Energy Efficient Outdoor Lighting … LED?”
  Dallas, TX - August 17, 2010

- **International Dark Sky Association Annual Meeting** - “Model Lighting Ordinance”
  Tucson, AZ - June 26, 2010

- **The Business of Clean Energy in Alaska Conference** - “Alaska’s Lighting Energy … Let’s Save 50% More”
  Anchorage, AK - June 17, 2010

- **Cooper Lighting** - “Exterior Lighting – Discussion”
  Peachtree, Georgia - March 9, 2010

- **IES Webinar** - “Exterior Lighting”
  Webinar - December 16, 2009

- **San Diego Gas & Electric and City of San Diego** - “Outdoor Lighting Study Update”
  San Diego, CA - October 27, 2009

- **E Source Lighting Forum** - “Latest on Outdoor Lighting”
  Denver, CO - September 24, 2009

- **IES Street and Area Lighting** - “Outdoor Lighting Committees’ Update”
  Philadelphia, PA - September 15, 2009

- **IES Street and Area Lighting** - “Tale of Two Cities”
  Philadelphia, PA - September 15, 2009

- **Aspen Institute and Rocky Mountain Institute** – “RMI Quest for Solutions” panel
Aspen, CO - August 11, 2009
- City of San Diego - “Streetlighting”
  San Diego, CA - August 6, 2009
- United States Army Corps Infrastructure Systems Conference - “Unified Facilities Criteria – Lighting” (with Richard Cofer)
  Cleveland, OH - July 22, 2009
  Honolulu, HI - May 9-10, 2009
- Clinton Climate Initiative - C40 Conference - “Outdoor Lighting” panel
  Seoul, South Korea - May 19, 2009
- City of Anchorage - “Outdoor Lighting Symposium (organizer, facilitator and speaker)”
  Anchorage, AK - December 4, 2008
- Xcel Energy - AFEC conference - “Energy Efficient Lighting”
  Denver, CO - November 12, 2008
- IESNA Street and Area Lighting - “Energy Efficient Outdoor Lighting”
  Denver, CO - September 15, 2008
- E Source – “Energy Efficient Exterior Lighting”
  Webinar - September 17, 2008
- LightFair International 2008 - “Healthy Daylight Healthy Darkness”
  New York, NY - May 27, 2008
- Fort Collins Energy Conference - “Greening Existing Buildings Nuts and Bolts – Keynote”
  Fort Collins, CO - January 24, 2008
- Illinois Public Radio - “Lighting Design for Efficiency and Beauty”
  Champagne, IL - January 2, 2008
- ASID Student Chapter - Colorado State University - “Sustainable Lighting Design”
  Fort Collins, CO - November 26, 2007
- Crites, Tidey & Associates Lighting Forum - “Sustainable Schools” and “Best in Retail Lighting”
  Grand Rapids, MI - September 26, 2007
- Greenprints 2007 – Master Series - “Advances in Lighting Technology”
  Atlanta, GA - March 22, 2007
- The Night Symposium - “The Night: Why Dark Hours Are So Important”
  Washington, DC - February 22, 2007
- State Energy Codes Meeting - “ASHRAE 90.1 2004 – Lighting Energy Code Section”
  (co-speaker with Eric Richman, PNNL, DOE)
  Denver, CO - January 28, 2007
- Austin School District and City of Austin Energy Office
  “High Performing Schools” (co speaker Bob Berkebile)
  Austin, TX - January 12, 2007
- IALD – Enlighten - “What’s New in Exterior Lighting Codes and Criteria?”
  San Diego, CA - October 20, 2006
- National Recreation and Parks Association - “Lighting Public Places”
  Colorado Springs, CO - September 2, 2006
- National workshop on State Building Energy Codes - “Lighting Code Comparisons”
  Denver, CO - September 1, 2006
- Neocon - “Sustainable Lighting for Interiors”
  Chicago, IL - June 12, 2006
- Lightfair International 2006 - “Beyond LEED” and “Security Lighting”
  Las Vegas, NV - May 29, 31, 2006
- New Mexico Lighting Alliance - “Lighting for Educational Facilities”
Santa Fe, NM - March 23, 2006
- International Dark Sky Association - “Model Lighting Ordinance”
  Tucson, AZ - March 16, 2006
- Osram Sylvania Executive Summit - “Putting It All Together”
  Naples, FL - January 30, 2006
- BC Hydro - “Quality Lighting for Sustainable Buildings”
  (with Lisa Heschong)
  Vancouver, BC - January 18, 2006
- Alaska Chapter CDFPI State Conference - “Quality Lighting for Educational Facilities”
  Anchorage, AK - December 2, 2005
- Municipality of Anchorage - Public Presentation - “Effective Outdoor Lighting in Northern Cities”
  Anchorage, AK - November 30, 2005
- BCHydro Power of Business Forum - “Effective Lighting for Health and Performance” (with Lisa Heschong)
  and “Exterior Lighting”
  Vancouver, BC - November 29, 2005
- Crites, Tidey & Associates Lighting Forum - “Retail Lighting” and “Outdoor Lighting – Dark Sky and Light Trespass”
  Grand Rapids, MI - September 14, 2005
- National Recreation and Park Association - “Lighting Public Spaces”
  Colorado Springs, CO - August 2, 2005
- New Mexico Heritage Preservation Alliance - “Are We Designing the Night Away? A Case for Design with the Night Sky in Mind”
  Santa Fe, NM - June 24, 2005
- City of Loveland - “Exterior Lighting”
  Loveland, CO - May 20, 2005
- Sustainable Arkansas Conference - “Lighting for People Not Footcandles”
  Little Rock, AR - May 5, 2005
- Denver Green Building Conference - “Planning for Light, Health and Comfort”
  Lakewood, CO - April 28, 2005
- Lightfair International 2005 - “Lighting of Educational Facilities”
  New York, NY - April 11, 2005
- Lightfair International 2005 - “Daylighting Institute – Retail Lighting” (with Greg Franta)
  New York, NY - April 10, 2005
- Northern Lights IES - “Quality Lighting for Educational Facilities”
  Anchorage, AK - October 7, 2004
- Dark Sky Public Forum - “Save the Night - Practical Solutions”
  Frisco, CO - September 17, 2004
- Engineering Green Buildings - “Lighting Controls”
  Cleveland, OH - July 21, 2004
- Efficiency Vermont - “Daylighting and Darkness for Human Health” and “Better Buildings by Design Conference”
  Burlington, VT - February 12, 2004
- Lighting Sciences Inc - Fall Foliage - “Retail Lighting” – keynote
  Newark, NJ - October 2003
- E Source Members Forum - “Exterior Lighting Design”
  Colorado Springs, CO - November 11, 2003
- Lightfair International - “Staying in Bounds . . . Outdoor Lighting Issues”
  New York, NY - May 7, 2003
- American Planning Association National Planning Conference - “Regulating Outdoor Lighting”
Denver, CO - March 30, 2003
- American Association for the Advancement of Science (AAAS) National Conference - “Outdoor Lighting”
- IALD Regional Conference - “Outdoor Lighting: Changes on the Horizon”
  San Francisco, CA - January 31, 2003
- Designers Lighting Forum - “Regulating Outdoor Lighting”
  Denver, CO - December 3, 2002
- Night Sky’s Symposium - Denver Museum of Nature and Science - “Putting It All Together: Creating Good Lighting”
  Denver, CO - November 21, 2002
- IALD National Conference - “Outdoor Lighting: Changes on the Horizon”
  Chicago, IL - November 15, 2002
- IESNA Annual Conference - “ETAL Studies and Applications”
  Salt Lake City, UT - August 6, 2002
- Lightfair - “New Product Showcase and Awards Presentation”
  San Francisco, CA - June 3, 2002
- AIA National Convention - “Integrated Design – The Consultant’s Point of View” (with Dan Nall)
  Charlotte, NC - May 9, 2002
- State of Arkansas Department of Economic Development - “Lighting Design – video Conference”
  Boulder, CO - June 11, 2002
- 17th Annual Electrical Exposition & Conference - “Outdoor Lighting That is Environmentally Friendly”
  New York, NY - June 17, 2002
- Greenprints - “Daylighting and Advanced Lighting Guidelines”
  Atlanta, GA - February 21, 2002
- International Facilities Management Association (IFMA) - “Lighting Design Energy Conscious, Incorporating daylighting, Cool looking stuff”
  Fort Collins, CO - February 13, 2002
- Western Electrical Exposition & Conference - “Outdoor Lighting That is Environmentally Friendly”
  Las Vegas, NV - February 12, 2002
- San Francisco IES Section at Chabot Observatory - “Dark Skies”
  Oakland, CA - January 17, 2002
- IES Section – Los Angeles - “Dark Skies”
  Los Angeles, CA - January 16, 2002
- IALD Annual Meeting - “Sustainability in Lighting Design”
  Philadelphia, PA - November 29, 2001
- Outdoor Lighting Education Forums - “Environmentally Sound Outdoor Lighting”
  Petoksey, MI - November 7, 2001
  Las Vegas, NV - May 30, 2001
  Atlanta, GA - March 15, 2001
- Rocky Mountain Section IES - “Sustainable Design”
  Denver, CO - March 13, 2001
- International Dark Sky Association - IDA Annual Meeting - “Panel of Experts”
  Tucson, AZ - March 9-11, 2001
Nancy Clanton – CV

  San Diego, CA - September 19, 2000
- IESNA Streetlighting Forum - “Quality Streetlighting”
  Minneapolis, MN - September 11, 2000
- EnvironDesign 4 Conference - “Preserving Our Connections with the Heavens”
  Denver, CO - May 20, 2000
- Lightfair International - “Sustainability: Illuminating the Big Picture through Design”
  New York, NY - May 8, 2000
- International Dark Sky Association - “Outdoor Lighting”
  Tucson, AZ - April 2000
- E Source Forum - “National Dimming Initiative”
  Colorado Springs, CO - October 1999
- Colorado Chapter International Dark Sky Association - “Light Pollution and Trespass from a Lighting Designers Point of View”
  Denver, CO - October 9, 1999
- IESNA Annual Conference - “Outdoor Light Trespass”
  New Orleans, LA - August 1999
  National Park Service/Colorado State University at Indiana State University
  - “Sustainable Practices – National teleconference”
  Bloomington, IN - May 6, 1999
- IESNA Annual Conference - “Outdoor Light Trespass”
  New Orleans, LA - August 10, 1999
- Vail Associates Green Development Services – Rocky Mountain Institute Workshop - “Beautiful and Efficient Lighting”
  Vail, CO - June 11, 1999
- NeoCon 99 - “Outdoor Lighting”
  Chicago, IL - June 8, 1999
- NeoCon 99 - “Retail Lighting: The Invisible Salesperson” (with Randy Burkett)
  Chicago, IL - June 7, 1999
- ELDA INTEL Light Fair - “Office Lighting” panel
  Milan, Italy - May 20, 1999
- Lighting Research Office – EPRI - International Lighting Research Symposium
  “A High Level Discussion of Low-Level Lighting – Panel”
  Orlando, FL - May 19 - 21, 1999
- IES Arizona Section - “Outdoor Environmental Lighting”
  Phoenix, AZ - January 19, 1999
- International Lighting Research Symposium - “A High-Level Discussion of Low-Level Lighting – panel”
  Orlando, FL - May 19-21, 1998
- EnvironDesign 2 - “Daylighting: Lighting Naturally”
  Monterey, CA - May 2, 1998
- Lightfair International - “Racheting Retail Lighting”
  New York, NY - May, 1998
- CU Earth Summit - “Architectural Elements: A Practical Discussion”
  Boulder, CO - April 21, 1998
- 3rd Annual Campus Earth Summit - University of Colorado at Boulder - “Green Building Techniques panel”
  Boulder, CO - February 6, 1996; February, 1998
- Globalcon '97 - “Lighting Efficiency Success Stories”
  Denver, CO - April 3, 1997
- Colorado Preservation, Inc. - “Historic Lighting Design”
  Denver, CO - February 6, 1998
- City of Austin - “Energy Efficient Lighting Design”
  Austin, TX - November 1, 1997; March 20, 1996
- 9th Annual E Source Members Forum - “Energy Efficient Lighting”
  Colorado Springs, CO - October 9, 1996
- Institute for the Built Environment - Colorado State University – Sustainable Projects 1996 Symposium
  Estes Park, CO - September 27, 1996
- Central Illinois Electrical League - “Lighting Seminar”
  Peoria, IL - April 11, 1996
- Association of Energy Engineers - “Energy Efficient Lighting Systems case studies”
  Denver, CO - April 4, 1996
  Asheville, NC - April 15, 1996
- Globalcon '96
  Denver, CO – 1996
- Las Vegas IES Section - “Integration of Natural and Electric Light Sources”
  Las Vegas, NV - January 10, 1996
- City of Longmont Electric Department Power Lunch - “Lighting for People, not Footcandles”
  Longmont, CO - September 14, 1995
- Denver ASID - “Illumination Specifying for the Interior Designer”
  Denver, CO - May 5, 1995
  Northern States Power and Minnesota Power Energy Workshop - “Lighting for People, Not Foot Candles”
  Minneapolis, MN - Tuesday, October 10, 1995
- AIA Utah Committee on Design and the Environment 1995 Design for Life Workshop “Lighting for People not Footcandles”
  Snowbird, UT - September 21-23, 1995
- FMI (Food Marketing Institute) - 16th Annual Energy & Technical Services Conference
  Maximizing Resources, Minimizing Costs - “Bright Lighting Ideas”
  Scottsdale, AZ - September 12, 1995
  Missoula, MT - April 18, 1995
  Northwest Electric Light & Power Association (NELPA) Dimension ’95 - “A Seminar for the Design Professional”
  Seattle, WA - March 8-10, 1995
- AIA International Teleconference - “Energy Efficient Lighting”
  Washington DC - January 14, 1994
- Professional Engineers of Colorado -“Successful Project Communication”
  Boulder, CO
The City of Seattle partnered with the Northwest Energy Efficiency Alliance to determine if lighting equipment choices and controls could save energy, without sacrificing safety. Clanton & Associates was hired to lead this research which included community preference. Key research questions were: “Are there visibility differences between HPS and LED Street lighting?” and “What is the public perception of safety with different street lighting systems?” This research stretched the boundaries of understanding regarding the visual impact of white light, and found that even at 25% light level under LED lighting in dry conditions, visibility or detection distances were similar to the 100% lighting levels. These findings have profound safety implications and energy impacts for communities hoping to change their lighting system from HPS to lower wattage LED.

**Scope of Work Performed**

Clanton & Associates developed and conducted the street lighting visibility research project with cooperation with Virginia Tech Transportation Institute. Subjective surveys were developed and collected from over 360 local residents on the comparison of different street lighting technologies. In addition, visibility tests were performed with 134 local participants in determining object detection differences between street lighting strategies.
Appendix B

Memorandum

To: Robin Leonard, Arlington County
   Erik Gutshall, Chairman, Williamsburg Lights Working Group

From: John Seymour, Working Group Member (E2C2)

Re: Outstanding Technical Questions — Williamsburg Field Lights

Date: May 10, 2016

If I understood you correctly at the Williamsburg Lights Scoping Meeting, you thought it would be useful to receive an updated list of technical questions that, to at least some members of the Williamsburg Lights Working Group, remain outstanding or incompletely answered. Below, I try to respond to that request.

At the outset I’d like to repeat that, except for Musco, no participant in Working Group activities to date has any experience with or real understanding of light physics. Some of the questions raised to date may reflect that lack of experience and understanding. Nevertheless, it is also fair to say that some technical questions raise significant concerns, at least in the minds of the requestors, and have not been fully or satisfactorily resolved.

1. **Glare**: The fundamental question about glare is simply whether the County can demonstrate convincingly that glare will not be present at levels that generate serious discomfort to nearby residents, occupants of the school, and users of the fields. This is a difficult question to answer, I realize. As Fairfax County concluded in its recent study of sports field lighting, glare is simply light that hinders or bothers the human eye and “no generally established methods for calculating acceptable levels of glare have been established in the sports lighting industry.” Fairfax County Park Authority, Athletic Field Lighting: Technical Report (2005) at 2-10. Similarly, a recent report issued by Carnegie-Mellon commented that “the substantial glare caused by LEDs is not typically included as a measurement criteria in evaluation processes and when it is, the tools of measurement are inadequate. As a result glare persists as an issue.” Carnegie-Mellon, LED Street Light Research Project (2011) at 43.

   As I understand it from the technical literature, there are several ways to estimate glare. One of the simplest is to measure the light emitted from the “worst case” luminaire. This “shorthand” measure has been adopted by Fairfax County, which recommends that, for rectangular fields with an edge of the playing field within 200’ from a residential property line, the maximum permitted glare is 7,000 candela. (Fairfax County Park Authority, Athletic Field Lighting Systems Performance Outline Specifications (July 28, 2010) at 5). Similarly, the British Institute of Lighting Engineers, in its “Guidance Notes for the Reduction of Light Pollution,” has established a maximum standard of 7,500 candela for residential neighborhoods.

   From the data in Musco’s photometrics, it is not entirely clear whether — even with 80’ poles — these limits will be met. For example, the photometrics provided in the draft Environmental Assessment indicate that light levels immediately north of the fields (where additional trailers will be installed) range up to more than 30,000 candela. Levels east of the site (toward the school) range up to 70,000 candela. Levels just short of the property line on the west (residential side of the fields) range up to 80,000 candela. It is unclear, from the data
given, whether levels at the property line west of the site exceed the 7,000 to 7,500 candela benchmarks at some locations — although some data points appear to approach those thresholds. In any event, the high levels of glare arising from the LED lights appears to be a real concern at this site, unresolved by the data generated to date.

It is also not entirely clear to us how the glare computations were made. As one researcher familiar with LED lights warned recently:

“a common mistake in measuring luminaire luminance is measuring the entire fixture. Luminance must be measured at the luminous opening, in other words at the smallest point (without any breaks) that emits light out of the fixture. If one were to measure the entire LED luminaire, it would not account for the ‘shards’ of light emitted from each individual LED. The light emitted from individual LED luminaire designs is more akin to a series of laser beams in contrast to the homogeneous output of a traditional luminaire.”

Nate Heiking, “Avoiding LED Glare Bombs,” LED Journal (Jan. 9, 2013). Thus, when Musco reports its glare measures (per light bank) or (per fixture), it is unclear to us whether predicted glare is being accurately modeled.

Finally, Working group members have raised a concern about reflected glare. As noted in the IESNA Recommended Practice for Sports and Recreation Lighting (RP-6-1) “glare can be caused by the luminaires or indirectly from the reflection of surrounding structures within the field of view.” Similarly, the International Commission on Illumination, in its “Technical Report: Guide on the Effects of Obtrusive Light From Outdoor Lighting Installations” (2003) has emphasized that lighting designers should consider the influence of reflected light on predicted glare levels. Sections 2.7.3 and 3.3.5. At the Williamsburg site, residents living west of the site have expressed concern about reflected glare onto their properties from intensely illuminated school structures and the field itself. Musco’s response to this concern, in part, is that reflected glare is not within Musco’s control and thus is not reflected in the design. Musco has also indicated that reflected glare can be difficult to measure and, with respect to the school structures, would be affected by the color and location of the structures. Although acknowledging these concerns, we continue to believe that reflected light may contribute significantly to glare and that the absence of such data represents a real gap in our understanding of potential lighting effects.

We note that, in addition to the “worst case luminaire” measure of glare, lighting authorities have recommended other measures as well. Fairfax County, in its White Paper: Athletic Field Lighting and Control of Obtrusive Light Pollution (2010) acknowledged that glare is difficult to measure and is “a result of source to background contrast ratio.” At 8. Accordingly, Working Group members had suggested that, as another rough measure of glare, Musco compute a source to ambient ratio. Musco’s written response to that question was simply that such testing could not be conducted and that it would need to “use a developmental program to check glare.” Because of the significance of the glare issue to residents and the difficulty of measuring or estimating glare generally, some Working Group members continue to believe that the County should devote additional resources to generate reliable predictors of glare — both direct and reflected. (Other commonly used measures of glare are the Glare Rating, developed by the International Commission on Illumination for outdoor lighting applications and the BUG (Backlight, Uplight and Glare rating).
2. **Light Pole Locations**: During Working Group discussions, members have raised questions about the locations of the poles. One threshold question is whether the design is fixed, or is still subject to revision. For example, concerns have been expressed that the current models likely do not accurately predict light spill and glare because the pole locations may need to be adjusted to accommodate additional school structures to be erected adjacent to the fields. Thus, absent a final decision on pole locations, the predictions of lighting effects likely have some inherent measure of uncertainty.

Second, concerns have been raised about the proposed location of light poles S-3 and S-4. Both the IESNA and FIFA have developed standards for pole locations at the perimeter of soccer fields. The aim of these standards is to protect users from disabling glare by prohibiting the placement of light poles near the mouth of goals or where corner kicks take place. In particular, the U.S. Soccer Foundation recommends that poles be located between the penalty line and the goal line. Poles S-3 and S-4 are located at the extreme corner of the two fields, behind the goal lines. From the design diagrams provided, it appears that the poles also may be located close to or within prohibited glare zones. IESNA, Recommended Practice for Sports and Recreational Lighting at 61, figure 81; U.S. Soccer Federation, Lighting Standards of the U.S. Soccer Federation (2007) at 13.

Finally, concerns have also been expressed whether the current design has properly factored in the needed set-back for poles, in light of the Zoning Ordinance requirements. Generally speaking, the higher the structure the greater the set-back. Zoning Ordinance section 3.2.6.A.2.e. Members are seeking assurance that the County’s drawings and plans properly respect minimum County set-back requirements for high structures.

3. **Aiming Angle**: Because luminaire aiming angles are critical to minimizing glare, we had asked whether the proposed poles would conform to generally recommended pole design specifications — that is, whether the upper level of the defined beam would be no more than 80 degrees above nadir. IESNA, Recommended Practice for Sports and Recreational Area Lighting, RP-6-01 (2001) at 18. In Musco’s written response to this concern, it stated that the poles could comply with this standard provided that it “can still achieve a minimum aiming angle of 24 degrees down from horizontal.” We don’t understand the response and ask whether, with pole heights at the County maximum, such compliance can be achieved. We also ask whether, if pole heights could be raised to 80’, such compliance could be achieved.

4. **Pole Height**: We have struggled, as you know, to understand the County’s requirements for pole height in S-3A zones. We had been advised, during Working Group deliberations, that the maximum height of poles in this zone is 68 feet. Zoning Ordinance section 4.2.3.A&B, section 3.1.6.B. But vertical distance must be measured from a calculated average elevation of the grade of the site at its perimeter— to ensure that builders do not bypass mandatory height limits by placing the structures at the highest point of a site. Zoning Ordinance section 3.1.6.A.2. As Robert Duffy indicated at our Scoping meeting (as I understood him), the average elevation of the overall Discovery site is 326’. My very quick review of the elevation of the 2 soccer fields themselves (using GoogleEarth) indicates that they average 334’. Based on the zoning ordinance, then, the maximum height of the structures (the light poles) should be in the neighborhood of 60’ — well below the heights at which most of the Musco modeling was performed.
I do understand, of course, that Musco has conceded that pole heights less than 70’ would produce objectionable levels of glare and thus has modeled lighting effects at 80’ — a height one-third higher than legally permissible in this S-3A zone. Nevertheless, we believe that the County should clearly state the permissible height limitation in this zone for light poles and also carefully consider, as part of its review, the visual impact (aesthetics, architectural harmony, visual clutter) of six 80’ light poles carrying a dozen luminaires each producing 63,600 lumens, on a historically dark and quiet residential neighborhood.

In that regard, we note the care with which Arlington County has historically approached this issue. In granting site plans and use permits in the past, Arlington has followed modern principles of urban design to protect neighborhood character and architectural harmony. In a rare approval of a waiver of height limitations for sports lighting, the County made specific findings at Long Bridge that a height increase is permissible because it is a “major recreational center, is bounded by major roads and intense development and additional height will not adversely affect neighboring properties.” Site Plan Amendment for North Tract Special Planning District (Nov. 15, 2006). At this site, of course, waiver of the height limitation would represent a marked change in the life-long expectations of residents about peace, quiet, and visual harmony in their R-10 residential setting.

5. Light Levels On The Field: When many of us visited the Vienna Little League baseball field lit with Musco LED lights, we were struck at the extraordinarily high levels of lighting on the field. The glare — particularly to those of us with aging eyes — was disabling. Musco’s January 2016 data for 80’ poles has indicated that light intensity (per light bank) will average more than 40,000 candelas with a maximum of 1.56 million candelas. Musco’s April 2016 data estimated even higher levels — a high of 1.9 million maintained candela (per light bank) with an average of 55,000 candela. Because these levels are extraordinarily high, we are seeking a better understanding of the propriety of these levels for field users, the likely effects on children using the field, and how those levels compare to those typically provided on soccer fields in residential neighborhoods where no or very few spectators are expected.

6. Dark Sky Compliance: To its credit, Arlington has consistently insisted that County lighting be Dark Sky compliant. Arlington County has stated that, because “[it] is committed to creating and maintaining a higher standard and quality of life for its residents, the Division of Transportation shall comply with Dark Sky regulations that attempt to reduce light spill pollution.” Arlington County, Street Light Policy and Planning Guide (updated June 2006) at 9. In a recent site plan approval memorandum, Arlington County approved the applicant’s lighting plan only after finding that it “incorporates the dark sky lighting principles in accordance with the standards of the International Dark Sky Association.” Site Plan Amendment for 1100 Wilson Boulevard (March 9, 2015). In the Environmental Assessment for the Discovery School itself, Arlington County noted that on-site lights “will be Dark Sky compliant to reduce light pollution and glare.” Discovery Environmental Assessment (Revised June 22, 2014) at 6.

The International Dark Sky Association (IDA) provides objective, third party certification for “Dark Sky” luminaires to minimize glare, reduce light trespass, and protect the nighttime sky. According to the IDA, however, lights of the temperature and color proposed by Musco would not be eligible to receive Dark Sky certification. The lights proposed by Musco are 5700 Kelvin, well above the 3,000 Kelvin temperature necessary to receive Dark Sky approval. As the IDA has repeatedly emphasized, outdoor lighting of the type proposed by Musco “is more likely to contribute to light pollution because it has a significantly larger geographic reach than lighting
with less blue light. Blue-rich white light sources are also known to increase glare and compromise human vision, especially in the aging eye.” IDA, LED Practical Guide (2016). The lights at issue, then, appear to violate long-established and sound policy to promote Dark Sky compliance in Arlington’s lighting initiatives.

In response to this concern, Musco indicated that warmer LED lights will result in higher initial and operating costs and might require an increase in luminaries and associated light spill. Given the very low levels of spill light predicted with 80’ poles, however, it’s unclear to me whether light spill should be a concern. Moreover, at least some investigators have concluded that high temperature units “contribute more to light pollution on a per lumen basis” than low temperature units. Ian Ashdown, Color Temperature and Outdoor Lighting (July 2015). Because blue light is preferentially scattered, resulting in higher levels of light pollution, it could be speculated that warmer luminaries (even if greater numbers are needed) would result in less light pollution. Moreover, as discussed earlier, the most significant issue with LED lights is glare. According to the IDA, outdoor lighting with blue-rich white light is more likely to contribute to light pollution because it has a significantly larger geographic reach than lighting with less blue light. Blue-rich white light sources are also known to increase glare and compromise human vision, especially in the aging eye.” IDA, Practical Guide (2015). For all of these reasons, members of the Working Group would find it helpful to review photometrics reflecting lighting of the fields with LED lights of 3,000 Kelvin or less.

7. Health and Environmental Effects: During Working Group deliberations, some members have requested from Musco all studies and reports in its possession bearing on the potential health and environmental effects from blue-white LED lighting. In its written response to this question, Musco denied having possession of any such studies and reports and stated further that, “no impact [will occur] due to the duration of the lighted venue and the color of the surface being lit will filter out the blue light. Additionally, control of light eliminates light on adjacent properties.”

Some Working Group members view this response skeptically, in light of the recent and robust scientific debate about potential health and environmental effects associated with intense LED lighting. I will not discuss this issue in depth here, because you have received more thorough discussions from other Working Group members. With respect Dark Sky compliance, however, the IDA has repeatedly cautioned that blue-white lights of the color temperature proposed for the Williamsburg site have been implicated in a host of adverse environmental and human health effects, including sleep deprivation. Other organizations, including the American Medication Association’s Council on Science and Public Health, the International Commission on Illumination, and the European Commission’s Scientific Committee on Emerging and Newly Identified Health Risks have issued similar warnings. In particular, the AMA has stated that even low levels of blue-spectrum light can disrupt melatonin production. If Musco has data confirming a dose-response relationship, or threshold and filtering effects relevant to sports lighting, it should provide such data to the Working Group.

8. Inability to Check Musco’s Data: Throughout this effort, the Working Group has relied exclusively on data provided by Musco. That data is, in turn, generated through the use of proprietary logarithms involving complex calculations and numerous assumptions and tradeoffs. The Working Group has no way of testing those logarithms, confirming the accuracy of the calculations, validating assumptions made, or evaluating the tradeoffs. Rather, we must take
the data as valid and replicable. Nor does it have any way to test the accuracy of Musco’s predictions of glare and light spill after-the-fact. Rather, they must be lived with.

The Working Group has acknowledged that, with respect to some issues, absolute certainty will not be attainable. Nevertheless, scientific uncertainty should be an occasion for caution. Indeed, the special use permit process itself properly incorporates a precautionary principle when it requires the County — before it may grant a permit — to make three separate showings. Arlington County may approve a permit or permit amendment only if it (1) will not affect adversely the health or safety of persons residing or working in the neighborhood of the proposed use; (2) be detrimental to the public welfare or injurious to property or improvements in the neighborhood; and (3) be in conflict with the master plans of the County.” Arlington Zoning Ordinance section 15.4.3.

Given the extraordinary levels of scientific, human health, and technical uncertainty surrounding the erection of numerous LED light poles in the Williamsburg neighborhood, both modern scientific precautionary principles and Arlington’s own laws mandate a very careful and deliberate review. It bears repeating here that, irrespective of the charge to the Working Group, the ultimate burden of demonstrating compliance with special use permit requirements lies with the County, not the Working Group. At least in the minds of some Working Group members, the record to date is very poorly developed and provides no basis for such a permit.
Musco Sports Lighting Responses to the information and questions shared by WFWG member John Seymour

The WFWG (Via workgroup member John Seymour) provided the following technical questions that raise significant concerns for workgroup members which in their view have not been fully or satisfactorily resolved. These questions were forwarded to Musco for their response. The following answers in blue were provided by Mr. Bradley D. Schlesselman, LC, Application Engineering Manager/Lighting Specialist, Musco Lighting and Technical Committee Member, International Dark-Sky Association.

1. **Glare:** The fundamental question about glare is simply whether the County can demonstrate convincingly that glare will not be present at levels that generate serious discomfort to nearby residents, occupants of the school, and users of the fields. This is a difficult question to answer, I realize. As Fairfax County concluded in its recent study of sports field lighting, glare is simply light that hinders or bothers the human eye and “no generally established methods for calculating acceptable levels of glare have been established in the sports lighting industry.” Fairfax County Park Authority, Athletic Field Lighting: Technical Report (2005) at 2-10. Similarly, a recent report issued by Carnegie-Mellon commented that “the substantial glare caused by LEDs is not typically included as a measurement criteria in evaluation processes and when it is, the tools of measurement are inadequate. As a result glare persists as an issue.” Carnegie-Mellon, LED Street Light Research Project (2011) at 43.

As I understand it from the technical literature, there are several ways to estimate glare. One of the simplest is to measure the light emitted from the “worst case” luminaire. This “shorthand” measure has been adopted by Fairfax County, which recommends that, for rectangular fields with an edge of the playing field within 200’ from a residential property line, the maximum permitted glare is 7,000 candela. (Fairfax County Park Authority, Athletic Field Lighting Systems Performance Outline Specifications (July 28, 2010) at 5). Similarly, the British Institute of Lighting Engineers, in its “Guidance Notes for the Reduction of Light Pollution,” has established a maximum standard of 7,500 candela for residential neighborhoods. From the data in Musco’s photometrics, it is not entirely clear whether — even with 80’ poles — these limits will be met. For example, the photometrics provided in the draft Environmental Assessment indicate that light levels immediately north of the fields (where additional trailers will be installed) range up to more than 30,000 candela. Levels east of the site (toward the school) range up to 70,000 candela. Levels just short of the property line on the west (residential side of the fields) range up to 80,000 candela. It is unclear, from the data given, whether levels at the property line west of the site exceed the 7,000 to 7,500 candela benchmarks at some locations — although some data points appear to approach those thresholds. In any event, the high levels of glare arising from the LED lights appears to be a real concern at this site, unresolved by the data generated to date.

**The glare (candela) values at the west residential property line will not exceed 7000 candela at any point along the property line, utilizing the 80’ pole option. Shorter poles would mean more glare impact at property line.**

It is also not entirely clear to us how the glare computations were made. As one researcher familiar with LED lights warned recently: “a common mistake in measuring luminaire luminance is measuring
the entire fixture. Luminance must be measured at the luminous opening, in other words at the smallest point (without any breaks) that emits light out of the fixture. If one were to measure the entire LED luminaire, it would not account for the ‘shards’ of light emitted from each individual LED. The light emitted from individual LED luminaire designs is more akin to a series of laser beams in contrast to the homogeneous output of a traditional luminaire.” Nate Heiking, “Avoiding LED Glare Bombs,” LED Journal (Jan. 9, 2013). Thus, when Musco reports its glare measures (per light bank) or (per fixture), it is unclear to us whether predicted glare is being accurately modeled.

The author of this article speaks in theory and not in practical terms. It is theoretically possible to isolate every source, take a measurement of the radiant energy being produced and predict a result. However, LED luminaires consist of arrays of LED sources which creates a composite beam. This beam exits the luminaire housing and is captured as one complete beam via a photometric report done typically using a gonio-photometer. It is not possible for the gonio-photometer to differentiate between sources contributing to each of the solid angles present exiting the luminaire, when an array is present. The guidelines produced by the IES also indicate that LED luminaires be tested as one complete unit, not as individual sources. For this reason, the practical nature of what the author is describing is not realistic. Furthermore, due to the small source size of the LED and the array layout that exists, along with the distance from observation point to luminaire location, the observer will most likely only see the composite of the entire beam, not just an individual source. As for the question, “Does Musco report glare measurements per light bank or per fixture?”, Musco can do either, but for most cases, including this one, we have shown per fixture.

Finally, working group members have raised a concern about reflected glare. As noted in the IESNA Recommended Practice for Sports and Recreation Lighting (RP-6-1) “glare can be caused by the luminaires or indirectly from the reflection of surrounding structures within the field of view.” Similarly, the International Commission on Illumination, in its “Technical Report: Guide on the Effects of Obtrusive Light From Outdoor Lighting Installations” (2003) has emphasized that lighting designers should consider the influence of reflected light on predicted glare levels. Sections 2.7.3 and 3.3.5. At the Williamsburg site, residents living west of the site have expressed concern about reflected glare onto their properties from intensely illuminated school structures and the field itself. Musco’s response to this concern, in part, is that reflected glare is not within Musco’s control and thus is not reflected in the design. Musco has also indicated that reflected glare can be difficult to measure and, with respect to the school structures, would be affected by the color and location of the structures. Although acknowledging these concerns, we continue to believe that reflected light may contribute significantly to glare and that the absence of such data represents a real gap in our understanding of potential lighting effects.

Musco could show the illuminance (amount of light) incident on the façade of the building structure. However, due to many unknowns about the material makeup of the building and the inability for the lighting design software to calculate, the information the Workgroup is asking for, cannot be presented. I can say the impact to the community from light bouncing off the building due to the proposed LED solution, will be negligible.

We note that, in addition to the “worst case luminaire” measure of glare, lighting authorities have recommended other measures as well. Fairfax County, in its White Paper: Athletic Field Lighting and
Control of Obtrusive Light Pollution (2010) acknowledged that glare is difficult to measure and is “a result of source to background contrast ratio.”

There are 4 main criteria to understanding the implications of glare. These are: 1. Luminance of the Source, 2. Background Luminance, 3. Adaptive State of the Eye, 4. Size of the Source. Until recent research conducted out of the University of Nebraska at Omaha by Dr. Yulia Tyukhova, there was not a metric that could be applied with respect to glare for off-site sports lighting applications. A research scholar could cite the CIE UGR metric as a possible metric for evaluating glare in sports lighting applications. However, it is known that this metric fails to compute credible values when source sizes are small and background luminances are near zero. When observing sports lighting venues, both of these characteristics are present while viewing the scene during nighttime events. Dr. Tyukhova, at the request of Musco, conducted her research to close the gap between the small source size and background luminances near zero. She has written a couple of papers on the research, which simply creates an extension to the existing UGR metric, however, these papers have not yet been published for the use of the lighting community. Furthermore, even if her metric was available for use, glare is a very subjective response by those who experience it. What may be glare to one individual may not be to another.

Accordingly, Working Group members had suggested that, as another rough measure of glare, Musco compute a source to ambient ratio. Musco’s written response to that question was simply that such testing could not be conducted and that it would need to “use a developmental program to check glare.”

Based on the research done by Dr. Tyukhova, Musco has developed a High Dynamic Range Imaging (HDRI) system which utilizes her research to better predict and evaluate off-site glare for neighboring communities. However, the papers need to be published and metrics need to be established before Musco can use this tool in commercial applications.

Because of the significance of the glare issue to residents and the difficulty of measuring or estimating glare generally, some Working Group members continue to believe that the County should devote additional resources to generate reliable predictors of glare — both direct and reflected. No need to do this as Dr. Tyukhova’s research will do this for you. (Other commonly used measures of glare are the Glare Rating (This is an on field metric and cannot be used off-site effectively), developed by the International Commission on Illumination for outdoor lighting applications and the BUG (Backlight, Uplight and Glare rating).

The BUG rating system is intended for fixed photometry only, meaning that the luminaires are always positioned in the same manner in every instance. Sports lighting applications, such as soccer fields, require aimable photometry. Because of this, it is not possible for an aimable sports lighting luminaire to gain the designation of the BUG rating system. I have had many conversations with the authors of the BUG system and I continue to fight them on this technicality. They repeatedly agree that the BUG system does not work with sports lighting applications.

2. Light Pole Locations: During Working Group discussions, members have raised questions about the locations of the poles. One threshold question is whether the design is fixed, or is still subject to revision. For example, concerns have been expressed that the current models likely do not accurately
predict light spill and glare because the pole locations may need to be adjusted to accommodate additional school structures to be erected adjacent to the fields. Thus, absent a final decision on pole locations, the predictions of lighting effects likely have some inherent measure of uncertainty.

*With the amount of work that Musco has placed into this project, I would hope that all of the foreseen pole placement issues have been resolved. Until foundations are in the ground, poles could always move. With that said, if pole locations need to move at this point, Musco would need to start this evaluation process again, which would be costly for the county and time consuming.*

Second, concerns have been raised about the proposed location of light poles S-3 and S-4. Both the IESNA and FIFA have developed standards for pole locations at the perimeter of soccer fields. The aim of these standards is to protect users from disabling glare by prohibiting the placement of light poles near the mouth of goals or where corner kicks take place. In particular, the U.S. Soccer Foundation recommends that poles be located between the penalty line and the goal line. Poles S-3 and S-4 are located at the extreme corner of the two fields, behind the goal lines. From the design diagrams provided, it appears that the poles also may be located close to or within prohibited glare zones. IESNA, Recommended Practice for Sports and Recreational Lighting at 61, figure 81; U.S. Soccer Federation, Lighting Standards of the U.S. Soccer Federation (2007) at 13.

*Musco assisted with the development of the USSF Lighting Guidelines, which is also the same parameters for IES and FIFA. The placement of poles S3 and S4, meet the Guidelines in question.*

Finally, concerns have also been expressed whether the current design has properly factored in the needed set-back for poles, in light of the Zoning Ordinance requirements. Generally speaking, the higher the structure the greater the set-back. Zoning Ordinance section 3.2.6.A.2.e. Members are seeking assurance that the County’s drawings and plans properly respect minimum County set-back requirements for high structures.

*Based on the current lighting plan, it appears that the proposed solution does indeed meet Ordinance Section 3.2.6.A.2.e. By our calculations the closest a pole can be to the property line, based on an 80’ pole, is 32’. The S3 pole is 60’ from the closest property line.*

3. **Aiming Angle:** Because luminaire aiming angles are critical to minimizing glare, we had asked whether the proposed poles would conform to generally recommended pole design specifications — that is, whether the upper level of the defined beam would be no more than 80 degrees above nadir. IESNA, Recommended Practice for Sports and Recreational Area Lighting, RP-6-01 (2001) at 18. In Musco’s written response to this concern, it stated that the poles could comply with this standard provided that it “can still achieve a minimum aiming angle of 24 degrees down from horizontal.” We don’t understand the response and ask whether, with pole heights at the County maximum, such compliance can be achieved. We also ask whether, if pole heights could be raised to 80’, such compliance could be achieved.

*The current design is for 80’ poles. The answer to the question is YES, this design does meet the 80 degree criteria. The 80 degree criteria could also be met with shorter poles, however, the candela
values at the property lines would go above the 7,000 cd value as discussed in question #1. Therefore, the 80’ pole option is still required, unless drastic on-field modifications are desired.

4. Pole Height: We have struggled, as you know, to understand the County’s requirements for pole height in S-3A zones. We had been advised, during Working Group deliberations, that the maximum height of poles in this zone is 68 feet. Zoning Ordinance section 4.2.3.A&B, section 3.1.6.B. But vertical distance must be measured from a calculated average elevation of the grade of the site at its perimeter— to ensure that builders do not bypass mandatory height limits by placing the structures at the highest point of a site. Zoning Ordinance section 3.1.6.A.2. As Robert Duffy indicated at our Scoping meeting (as I understood him), the average elevation of the overall Discovery site is 326’. My very quick review of the elevation of the 2 soccer fields themselves (using Google Earth) indicates that they average 334’. Based on the zoning ordinance, then, the maximum height of the structures (the light poles) should be in the neighborhood of 60’ — well below the heights at which most of the Musco modeling was performed. I do understand, of course, that Musco has conceded that pole heights less than 70’ would produce objectionable levels of glare and thus has modeled lighting effects at 80’ — a height one-third higher than legally permissible in this S-3A zone. Nevertheless, we believe that the County should clearly state the permissible height limitation in this zone for light poles and also carefully consider, as part of its review, the visual impact (aesthetics, architectural harmony, visual clutter) of six 80’ light poles carrying a dozen luminaires each producing 63,600 lumens, on a historically dark and quiet residential neighborhood.

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5. Light Levels On The Field: When many of us visited the Vienna Little League baseball field lit with Musco LED lights, we were struck at the extraordinarily high levels of lighting on the field. The glare — particularly to those of us with aging eyes — was disabling. Musco’s January 2016 data for 80’ poles has indicated that light intensity (per light bank) will average more than 40,000 candelas with a maximum of 1.56 million candelas. Musco’s April 2016 data estimated even higher levels — a high of 1.9 million maintained candela (per light bank) with an average of 55,000 candela. Because these levels are extraordinarily high, we are seeking a better understanding of the propriety of these levels for field users, the likely effects on children using the field, and how those levels compare to those typically provided on soccer fields in residential neighborhoods where no or very few spectators are expected.

I am guessing that the visit to Vienna was for the purposes of an off-site demonstration. I gather there weren’t any issues from the Working Group for off-site control at this facility. For the sake of on-field evaluation, simply put, you picked a site that is completely different than what this project is about. The little league field you visited had light levels at least twice as high as what is being proposed for this site. The references to the maximum candela values are on field variables that are
not pertinent to the discussion about protecting the neighboring properties. However, since it was brought up, I will say that these values are well within the range of every, I mean every, recreational baseball, softball, and soccer field that exists in the nation today, where light levels are similar to the proposed.

6. Dark Sky Compliance: To its credit, Arlington has consistently insisted that County lighting be Dark Sky compliant. Arlington County has stated that, because “[it] is committed to creating and maintaining a higher standard and quality of life for its residents, the Division of Transportation shall comply with Dark Sky regulations that attempt to reduce light spill pollution.” Arlington County, Street Light Policy and Planning Guide (updated June 2006) at 9. In a recent site plan approval memorandum, Arlington County approved the applicant’s lighting plan only after finding that it “incorporates the dark sky lighting principles in accordance with the standards of the International Dark Sky Association.” Site Plan Amendment for 1100 Wilson Boulevard (March 9, 2015). In the Environmental Assessment for the Discovery School itself, Arlington County noted that on-site lights “will be Dark Sky compliant to reduce light pollution and glare.” Discovery Environmental Assessment (Revised June 22, 2014) at 6.

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In response to this concern, Musco indicated that warmer LED lights will result in higher initial and operating costs and might require an increase in luminaries and associated light spill. Given the very low levels of spill light predicted with 80’ poles, however, it’s unclear to me whether light spill should be a concern. Moreover, at least some investigators have concluded that high temperature units “contribute more to light pollution on a per lumen basis” than low temperature units. Ian Ashdown, Color Temperature and Outdoor Lighting (July 2015). Because blue light is preferentially scattered, resulting in higher levels of light pollution, it could be speculated that warmer luminaries (even if greater numbers are needed) would result in less light pollution. Moreover, as discussed earlier, the most significant issue with LED lights is glare. According to the IDA, outdoor lighting with blue-rich white light is more likely to contribute to light pollution because it has a significantly larger geographic reach than lighting with less blue light. Blue-rich white light sources are also known to increase glare and compromise human vision, especially in the aging eye.” IDA, Practical Guide (2015). For all of these reasons, members of the Working Group would find it helpful to review photometrics reflecting lighting of the fields with LED lights of 3,000 Kelvin or less.

As a member of the IDA Technical Committee as well as the Musco Engineer responding to this inquiry, I am going to defer question #6 to Chris Monrad, Electrical Engineer, Monrad Engineering, Tucson, AZ, who is also a member of the IDA Technical Committee. He will tell you how the IDA feels
about the proposed Musco solution. Also see the Oct. 12, 2015 update to Ian Ashdown’s blog (as cited above) for the rest of the story regarding color temperature for sports lighting applications.

"Below is the link to Ian Ashdown’s blog that was referenced in the May 10, 2016 inquiry. Please see the update posted on Oct. 12, 2015, regarding the blue content and the effect on field turf/grass. 

http://agi32.com/blog/category/correlated-color-temperature-cct/

I have also attached a couple Spectral Power Distributions (SPD) for various LED CCT sources and also for the legacy metal halide (MH) sources that have been utilized in sports lighting applications for the better part of 40 years. The percentage of lumens in the "Blue" range, for each, is listed on each of the documents. Note, due to the applied inefficiency of the MH compared to either of the LED sources, there will be a 92% greater total impact in the blue content for the legacy source than the 5000K CCT LED source. I took the existing MH design and LED design information, along with the attached SPD information to derive the 92% value. (see attached "Blue Content Hand Calcs")

7. Health and Environmental Effects: During Working Group deliberations, some members have requested from Musco all studies and reports in its possession bearing on the potential health and environmental effects from blue-white LED lighting. In its written response to this question, Musco denied having possession of any such studies and reports and stated further that, “no impact [will occur] due to the duration of the lighted venue and the color of the surface being lit will filter out the blue light. Additionally, control of light eliminates light on adjacent properties.”

Some Working Group members view this response skeptically, in light of the recent and robust scientific debate about potential health and environmental effects associated with intense LED lighting. I will not discuss this issue in depth here, because you have received more thorough discussions from other Working Group members. With respect Dark Sky compliance, however, the IDA has repeatedly cautioned that blue-white lights of the color temperature proposed for the Williamsburg site have been implicated in a host of adverse environmental and human health effects, including sleep deprivation. Other organizations, including the American Medication Association’s Council on Science and Public Health, the International Commission on Illumination, and the European Commission’s Scientific Committee on Emerging and Newly Identified Health Risks have issued similar warnings. In particular, the AMA has stated that even low levels of blue-spectrum light can disrupt melatonin production. If Musco has data confirming a dose-response relationship, or threshold and filtering effects relevant to sports lighting, it should provide such data to the Working Group.

Musco does not have the data the Working Group is looking for, because the data simply does not exist. Even within the medical community, if you look at all the papers going against “Blue Light” the conclusions are that more research is needed to confirm or deny the claims. I recommend the Working Group contact Brian Leibel, Technical Director of Standards, IESNA for his comments on the actual research conducted in this area and ask him for the documentation (he doesn’t have it because it doesn’t exist.) Lots of hype being made about something that MIGHT exist. The Working Group could also contact Bruce Kinzey, Pacific Northwest National Laboratory (PNNL), about the hype. A memo from him dated July 2016 has been attached.
8. Inability to Check Musco’s Data: Throughout this effort, the Working Group has relied exclusively on data provided by Musco. That data is, in turn, generated through the use of proprietary logarithms involving complex calculations and numerous assumptions and tradeoffs. 

**This is why the county is asking someone (me) who is Lighting Certified through the National Council on Qualifications for the Lighting Professions (NCQLP) for assistance on the matter.**

The Working Group has no way of testing those logarithms, confirming the accuracy of the calculations, validating assumptions made, or evaluating the tradeoffs. **This happens every day in the lighting profession. In the end, it is up to the lighting professional to make sure specifications are met.**

Rather, we must take the data as valid and replicable. Nor does it have any way to test the accuracy of Musco’s predictions of glare and light spill after-the-fact. Rather, they must be lived with.

**Musco will make sure that the end result is brought to within project specifications. It is guaranteed in writing.**

The Working Group has acknowledged that, with respect to some issues, absolute certainty will not be attainable. Nevertheless, scientific uncertainty should be an occasion for caution. Indeed, the special use permit process itself properly incorporates a precautionary principle when it requires the County — before it may grant a permit — to make three separate showings. Arlington County may approve a permit or permit amendment only if it (1) will not affect adversely the health or safety of persons residing or working in the neighborhood of the proposed use; (2) be detrimental to the public welfare or injurious to property or improvements in the neighborhood; and (3) be in conflict with the master plans of the County.” Arlington Zoning Ordinance section 15.4.3.

Given the extraordinary levels of scientific, human health, and technical uncertainty surrounding the erection of numerous LED light poles in the Williamsburg neighborhood, both modern scientific precautionary principles and Arlington’s own laws mandate a very careful and deliberate review. It bears repeating here that, irrespective of the charge to the Working Group, the ultimate burden of demonstrating compliance with special use permit requirements lies with the County, not the Working Group. At least in the minds of some Working Group members, the record to date is very poorly developed and provides no basis for such a permit.

**As a lighting professional, my job is lighting something the very best way possible. With that said, if the Working Group is looking for the very best sports lighting solution at recreational lighting levels for the betterment of the community, you will not find a better solution than what has been provided. As a long time (18 years) Lighting Designer, member of both the IES and International Dark-Sky Association, and scientific researcher of lighting for both sports and general lighting, I appreciate the diligent effort taken by the Working Group to make sure that this is the very best solution for the community.**

**Lastly, the legacy sources (metal halide) utilized in sports lighting applications over the past 40 years have likely contributed more to the potential “Blue Light to Human Health” hazard than the highest**
CCT LED sources being promoted today. This is based on information gathered from the Kinzey article. If a reduction in “Blue Light” is truly the mission, then a large and focused effort should be placed on retrofitting all legacy (metal halide) sports lighting projects to LED sports lighting products where extreme light control is possible.
4000K LED
405nm and 530nm = 30.46%
5000K LED
405nm and 530nm = 36.15%
Metal Halide
405nm and 530nm = 30.64%
Hello MSSLC Members:

I imagine most everyone is familiar with the recent position statement issued by the American Medical Association (AMA) on "high-intensity street lighting," due to the extensive media coverage following its release. We continue to field inquiries that include many passed along from our member municipalities and utilities, originating from their citizens and customers. The messages contained in the release have caused a stir.

DOE's Solid-State Lighting Program issued an SSL Postings within a few days of the AMA's release. This notes the importance of matching the characteristics of the product with the specific application, underscoring the AMA's call for the use of appropriate products. Since then a number of other organizations have also weighed in with very useful perspectives. You might want to check these out if you haven't already:

- Glenn Heinmiller of LAM Partners in Cambridge, MA, responded to a number of the AMA points and subsequent misinterpretations in the media coverage that immediately followed the release; Glenn was directly involved with the street lighting conversion in Cambridge that was referenced in the AMA's statement.
- The Lighting Research Center at RPI responded with a mix of technical discussion and concise topic-by-topic summaries to clarify some central points. They note that two key contributors to the influence of blue wavelengths on health include intensity and the amount of exposure time of the retina, both of which were left out of the AMA statement.
- The National Electrical Manufacturer's Association has also weighed in, reiterating the potential for controlling light distribution from LED products and noting that one color temperature (3000K) will not be appropriate for all applications.

In addition to the above I thought I might also provide some numbers for your use should you continue to get inquiries from your respective agencies and citizens. Probably most people do not have access to the actual spectral contents of the different types of lighting in common use or know how they compare with one another, even if they understand that
virtually all lighting sources produce some amount of melanopic content. Melanopic content is of interest here because it is regarded as a primary indicator of the relative potential for the listed light sources to stimulate the human biological responses that are the subject of much of the AMA’s statement. Note, however, that influences from other photoreceptors like the rods and cones are also known to contribute to biological responses such as circadian and neurophysiological regulation, but in ways that are not fully clear to the medical research community.

Table 1 lists various sources used in street and area lighting and selected performance characteristics related to their spectral content. Data for each source includes a measured Correlated Color Temperature (CCT), the calculated percentage of radiant power contained in "blue wavelengths" (defined here from the literature related to sky glow as wavelengths between 405 and 530 nanometers [nm]), and the corresponding scotopic and melanopic multipliers relative to a high-pressure sodium (HPS) baseline, normalized for equivalent lumen output. Note that research on the contributions of different types of photoreceptors to visual and non-visual responses continues (e.g., see Amundadottir, 2016; Schlangen, 2016; Lucas et al., 2014) and may warrant updates to this table in the future.

**Table 1. Selected blue light characteristics of various outdoor lighting sources at equivalent lumen output.**

<table>
<thead>
<tr>
<th>Row</th>
<th>Light source</th>
<th>CCT (K)</th>
<th>% Blue*</th>
<th>Luminous Flux (lm)</th>
<th>Scotopic content relative to HPS</th>
<th>Melanopic content relative to HPS**</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>PC white LED</td>
<td>2700</td>
<td>17% - 20%</td>
<td>1000</td>
<td>1.77 - 1.82</td>
<td>1.90 - 2.06</td>
</tr>
<tr>
<td>B</td>
<td>PC white LED</td>
<td>3000</td>
<td>16% - 25%</td>
<td>1000</td>
<td>1.89 - 2.13</td>
<td>2.10 - 2.51</td>
</tr>
<tr>
<td>C</td>
<td>PC white LED</td>
<td>3500</td>
<td>22% - 27%</td>
<td>1000</td>
<td>2.04 - 2.37</td>
<td>2.34 - 2.97</td>
</tr>
<tr>
<td>D</td>
<td>PC white LED</td>
<td>4000</td>
<td>27% - 32%</td>
<td>1000</td>
<td>2.10 - 2.65</td>
<td>2.35 - 3.40</td>
</tr>
<tr>
<td>E</td>
<td>PC white LED</td>
<td>4500</td>
<td>31% - 35%</td>
<td>1000</td>
<td>2.35 - 2.85</td>
<td>2.75 - 3.81</td>
</tr>
<tr>
<td>F</td>
<td>PC white LED</td>
<td>5000</td>
<td>34% - 39%</td>
<td>1000</td>
<td>2.60 - 2.89</td>
<td>3.18 - 3.74</td>
</tr>
<tr>
<td>G</td>
<td>PC white LED</td>
<td>5700</td>
<td>35% - 43%</td>
<td>1000</td>
<td>2.77 - 3.31</td>
<td>3.44 - 4.52</td>
</tr>
<tr>
<td>H</td>
<td>PC white LED</td>
<td>6500</td>
<td>43% - 48%</td>
<td>1000</td>
<td>3.27 - 3.90</td>
<td>4.38 - 5.84</td>
</tr>
<tr>
<td>I</td>
<td>Narrowband amber LED</td>
<td>1606</td>
<td>0%</td>
<td>1000</td>
<td>0.36</td>
<td>0.12</td>
</tr>
<tr>
<td>J</td>
<td>Low pressure sodium</td>
<td>1719</td>
<td>0%</td>
<td>1000</td>
<td>0.35</td>
<td>0.10</td>
</tr>
<tr>
<td>K</td>
<td>PC amber LED</td>
<td>1872</td>
<td>1%</td>
<td>1000</td>
<td>0.70</td>
<td>0.42</td>
</tr>
<tr>
<td>L</td>
<td>High pressure sodium</td>
<td>1959</td>
<td>9%</td>
<td>1000</td>
<td>0.89</td>
<td>0.86</td>
</tr>
<tr>
<td>M</td>
<td>High pressure sodium</td>
<td>2041</td>
<td>10%</td>
<td>1000</td>
<td><strong>1.00</strong></td>
<td><strong>1.00</strong></td>
</tr>
<tr>
<td>N</td>
<td>Incandescent</td>
<td>2851</td>
<td>12%</td>
<td>1000</td>
<td>2.26</td>
<td>2.79</td>
</tr>
<tr>
<td>O</td>
<td>Halogen</td>
<td>2934</td>
<td>13%</td>
<td>1000</td>
<td>2.28</td>
<td>2.81</td>
</tr>
<tr>
<td>P</td>
<td>F32T8/830 fluorescent</td>
<td>2940</td>
<td>20%</td>
<td>1000</td>
<td>2.02</td>
<td>2.29</td>
</tr>
<tr>
<td>Q</td>
<td>Metal halide</td>
<td>3145</td>
<td>24%</td>
<td>1000</td>
<td>2.16</td>
<td>2.56</td>
</tr>
<tr>
<td>R</td>
<td>F32T8/835 fluorescent</td>
<td>3450</td>
<td>28%</td>
<td>1000</td>
<td>2.37</td>
<td>2.87</td>
</tr>
<tr>
<td>S</td>
<td>F32T8/841 fluorescent</td>
<td>3965</td>
<td>30%</td>
<td>1000</td>
<td>2.58</td>
<td>3.18</td>
</tr>
<tr>
<td>T</td>
<td>Metal halide</td>
<td>4002</td>
<td>33%</td>
<td>1000</td>
<td>2.53</td>
<td>3.16</td>
</tr>
<tr>
<td>U</td>
<td>Metal halide</td>
<td>4041</td>
<td>35%</td>
<td>1000</td>
<td>2.84</td>
<td>3.75</td>
</tr>
</tbody>
</table>

* Percent blue calculated according to LSPDD: Light Spectral Power Distribution Database, [http://galileo.graphycs.cegepsherbrooke.qc.CA/app/en/home](http://galileo.graphycs.cegepsherbrooke.qc.CA/app/en/home). The specific calculation, developed for evaluating the potential for affecting sky glow, divides the radiant power contained in the wavelengths between 405 and 530 nm by the total radiant power contained from 380 to 780 nm, for each light source.

** Melanopic content calculated according to CIE Irradiance Toolbox, [http://files.cie.co.at/784_TN003_Toolbox.xls](http://files.cie.co.at/784_TN003_Toolbox.xls), 2015 as derived from Lucas et al., 2014.

**Key:** PC -- Phosphor Converted; LED -- Light Emitting Diode
As most products differ slightly from one another, the scotopic and melanopic values presented should be taken as being typical for the associated light source type, rather than exact. We have included ranges, for which we have data, to indicate the upper and lower limits that might be found in a representative set of LED product samples. The number of product samples underlying each CCT ranges from 2 (for 2700 K) to 19 (for 3000 K), with others falling in between (76 samples in all). Conventional light sources are all listed with single values rather than a range because DOE has performed less testing on those, but they would likewise be most accurately characterized by a range (albeit narrower than LED).

It is important to understand that performing a calculation with these values only provides an idea of the relative potential to cause human health impacts, rather than the actual (if any) impact of the melanopic content. These values do not yet take into account several critically-contributing factors noted in the LRC paper linked above, such as the intensity one might expect to find inside a bedroom from a streetlight outside. Furthermore, the melanopic content itself directly scales with light output for a given source, so reducing output by dimming dynamically reduces the corresponding content.

Finally, note that the scotopic and melanopic contents reported are listed relative to HPS, which was selected as the baseline for comparison due to its predominance in the existing outdoor lighting market.

The influence of blue wavelengths is immediately evident in all "white light" sources containing them. In addition, as demonstrated by the relative melanopic contents of conventional lighting sources in the table, the blue light issues being raised by the AMA are clearly nothing new to our lighted environment. What is new is our increased understanding of their potential influence regarding human and environmental health issues, as the related research progresses.

**Estimating the potential impacts**

A commonly cited advantage of LED lighting is the superior control available over its light distribution. This advantage arises because a luminaire needs to fit its output to a target area, for example a rectangular stretch of roadway extending 100+ feet out from under each side of a streetlight. To satisfy the application, fixtures employing omni-directional emitters like glass lamps require significant reshaping of the lamp's output through reflectors and lenses, and despite great skill in this regard, the results remain far from perfect with large components of the light continuing to exit the fixture in unwanted directions. The latter often results in light trespass, glare, uplight (in older installations especially) and non-uniform illumination on the ground, all of which amount to wasted light and energy. In contrast, because LEDs emit in only one hemispherical direction, the optics' job of shaping their light output into the pattern wanted is much easier from the start, and thereby enables the elimination of much of this waste.

One direct benefit resulting from the improved distribution is that lamp-based fixtures are now routinely being replaced with LED products that emit only half (or less) of the light output of the replaced conventional light source. This is a key concept for estimating the potential for impact from a lighting conversion program. For example, if product X has a melanopic content twice that of product Y, but can be run at one-third the output, then converting to product X might actually reduce melanopic output. As previously noted, dimming a given product similarly reduces its emitted melanopic content, in direct proportion to the reduced light output.
Numerous real-world examples exist of such reductions being achieved in actual street lighting conversion programs around the U.S. As a salient example, the city where I live, Portland, OR, has replaced its previous 100 W HPS fixtures emitting about 9,000 lumens (initial) with 4000 K LED products that are set to an initial output of 3,000 lumens, achieving a two-thirds reduction. As a result, in absolute terms, the LED products in Portland have likely had little impact on the melanopic output compared to the previous (and notably non-white) HPS fixtures they replaced, because the reduced light output offsets the LED's higher melanopic multiplier.

A second example is Cambridge, MA, which installed a dimming control system when it converted its street lighting to LED in 2013. According to a complete inventory of its lighting system at the time, the city replaced a total of about 54 million lumens (initial) of HPS lighting with about 32 million lumens (initial) of 4000 K LED lighting. The city's "maintained" setting of the controls system is at 70% output, meaning it actually only uses about 22.4 million lumens to light its streets at dusk when the lights first come on. Moreover, at midnight the dimmer setting is further reduced by another 50% (i.e., to 35% of full output), where it remains until early morning. Assuming even a high melanopic content factor relative to the original HPS of 3.4, during the initial evening hours its relative melanopic content emissions would amount to 3.4 x (22.4/54) = 1.41x those of the original HPS system. From midnight to the early morning hours, this value is reduced again by 0.5, yielding a factor of about 0.71x. In other words, the Cambridge system has offset the increase in melanopic content of converting to 4000 K lights, at least during the middle of the night, by reducing their output while still gaining the benefits of improved visibility, reduced energy and maintenance, and increased lifetime and reliability.

To summarize a few key takeaways:

- The spectral content of a light source determines its melanopic content and can thereby be used to help in selecting the associated level of melanopic content of a system. In contrast, while CCT is acceptable as a first approximation of spectral content, it is a less accurate measure of relative melanopic content than SPD. The significant overlap between melanopic contents of PC White LEDs at 3000 K and 4000 K in the table, for example, shows that simply substituting a 3000 K product for a 4000 K product may not necessarily accomplish the intended result.
- The "raw" melanopic content produced by a light source is only one contributor to any ensuing environmental or health impacts actually realized. Focusing exclusively on that measure (or any single measure, such as CCT) ignores the various means of controlling or offsetting the increased melanopic content of white light sources, and particularly those noted (e.g., greatly improved distribution, dimming capability) that are enabled by LED technology.
- The ranges in melanopic content available among LED products suggest that LEDs offer substantial flexibility towards tailoring them to the specific application.
- For a given light source, output from the luminaire is directly related to its emitted level of melanopic content, so reducing initial output (as in the Portland example) or dimming the system (as Cambridge does after midnight) offer direct, easily realized reductions in this regard.

The real value in LEDs, as has been stressed all along, comes from the combination of these elements. The wide-ranging capabilities and characteristics of LEDs are greater than any other lighting source that has come before them, and thus they offer unparalleled potential for addressing the issues raised by the AMA. As noted in the SSL Postings, LEDs are a critical part of the solution provided that these functionalities are applied. This is the message that should be shared.
I hope this information is helpful in planning and understanding the potential impacts of your own conversion efforts. I would like to extend my sincere thanks to George Brainard, Ph.D., and Robert Lucas, Ph.D., who reviewed and commented on this issue of *The Light Post* for accuracy. Their assistance is greatly appreciated.

Bruce Kinzey, MSSLC Director  
Pacific Northwest National Laboratory  
[MSLSC@pnnl.gov](mailto:MSLSC@pnnl.gov)
48% Lens "Blue"
14 LED 5000K

(Compared to MH)

<table>
<thead>
<tr>
<th>MH</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu - 501</td>
<td>0.58 Cu</td>
</tr>
<tr>
<td></td>
<td>- 502 - 0.55</td>
</tr>
<tr>
<td></td>
<td>- 502 - 0.72</td>
</tr>
</tbody>
</table>

% 1: 330 x 198
- 77 grid point x 96 = 69,360

% 2: 320 x 180
- 60 grid point x 96 = 57,600

% 1: 1,386,000 lumens needed

<table>
<thead>
<tr>
<th>MH</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>134,000</td>
<td>63,600 km</td>
</tr>
<tr>
<td>238,965 lumens generated</td>
<td>180,000 lumens generated</td>
</tr>
<tr>
<td>1,086,000 lumens not on target</td>
<td>474,000 lumens not on target</td>
</tr>
</tbody>
</table>

% 2: 1,080,000 lumens needed.

<table>
<thead>
<tr>
<th>MH</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td>134,000</td>
<td>63,600 km</td>
</tr>
<tr>
<td>196,360 lumens generated</td>
<td>150,000 lumens generated</td>
</tr>
<tr>
<td>883,630 lumens not on target</td>
<td>470,000 lumens not on target</td>
</tr>
</tbody>
</table>

Total: 1887,291 lumens not on target

LED: 63,600 lumens

LEO: 70,152

% 1: 53,246 lumens - 478,246 lumens
% 2: 401,491 lumens
### Lighting System

**Pole / Fixture Summary**

<table>
<thead>
<tr>
<th>Pole ID</th>
<th>Pole Height</th>
<th>Mtg Height</th>
<th>Fixture Qty</th>
<th>Luminaire Type</th>
<th>Load</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1-S2</td>
<td>80’</td>
<td>80’</td>
<td>10</td>
<td>216 LED</td>
<td>5.97 kW</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>228 LED</td>
<td>0.63 kW</td>
<td>A</td>
</tr>
<tr>
<td>S3</td>
<td>80’</td>
<td>80’</td>
<td>6</td>
<td>216 LED</td>
<td>3.58 kW</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>216 LED</td>
<td>1.79 kW</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>228 LED</td>
<td>3.78 kW</td>
<td>A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>228 LED</td>
<td>3.78 kW</td>
<td>B</td>
</tr>
<tr>
<td>S4</td>
<td>80’</td>
<td>80’</td>
<td>3</td>
<td>216 LED</td>
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<td></td>
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<td>216 LED</td>
<td>2.99 kW</td>
<td>A</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>228 LED</td>
<td>3.78 kW</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>228 LED</td>
<td>4.41 kW</td>
<td>A</td>
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<tr>
<td>S5-S6</td>
<td>80’</td>
<td>80’</td>
<td>10</td>
<td>216 LED</td>
<td>5.97 kW</td>
<td>B</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>216 LED</td>
<td>5.97 kW</td>
<td>B</td>
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</table>

**Group Summary**

<table>
<thead>
<tr>
<th>Group</th>
<th>Description</th>
<th>Load</th>
<th>Fixture Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Soccer 1</td>
<td>27.96 kW</td>
<td>46</td>
</tr>
<tr>
<td>B</td>
<td>Soccer 2</td>
<td>23.08 kW</td>
<td>38</td>
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</table>

**Fixture Type Summary**

<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
<th>Wattage</th>
<th>Lumens</th>
<th>L90</th>
<th>L80</th>
<th>L70</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>228 LED</td>
<td>LED 5700K - 75 CRI</td>
<td>630W</td>
<td>63,600</td>
<td>33,000</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td>27</td>
</tr>
<tr>
<td>216 LED</td>
<td>LED 5700K - 75 CRI</td>
<td>597W</td>
<td>63,600</td>
<td>33,000</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td>57</td>
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</table>

**Light Level Summary**

**Calculation Grid Summary**

<table>
<thead>
<tr>
<th>Grid Name</th>
<th>Calculation Metric</th>
<th>Ave</th>
<th>Min</th>
<th>Max</th>
<th>Max/Min</th>
<th>Groups</th>
<th>Fixture Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>100’ Spill</td>
<td>Horizontal</td>
<td>0.02</td>
<td>0.00</td>
<td>0.13</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
</tr>
<tr>
<td>100’ Spill</td>
<td>Max Candela (by Fixture)</td>
<td>4389</td>
<td>0.00</td>
<td>20572</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
</tr>
<tr>
<td>100’ Spill</td>
<td>Max Vertical Illuminance</td>
<td>0.06</td>
<td>0.00</td>
<td>0.27</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
</tr>
<tr>
<td>200’ Spill</td>
<td>Horizontal</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
</tr>
<tr>
<td>200’ Spill</td>
<td>Max Candela (by Fixture)</td>
<td>180</td>
<td>0.00</td>
<td>1747</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
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<tr>
<td>200’ Spill</td>
<td>Max Vertical Illuminance</td>
<td>0.00</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
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<tr>
<td>Blanket Grid</td>
<td>Horizontal</td>
<td>1.21</td>
<td>0.00</td>
<td>42</td>
<td>0.00</td>
<td>A</td>
<td>46</td>
</tr>
<tr>
<td>Blanket Grid</td>
<td>Max Candela (by Light Bank)</td>
<td>28933</td>
<td>0.00</td>
<td>140906</td>
<td>0.00</td>
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<tr>
<td>Blanket Grid</td>
<td>Max Vertical Illuminance</td>
<td>1.60</td>
<td>0.00</td>
<td>55</td>
<td>0.00</td>
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<td>46</td>
</tr>
<tr>
<td>Soccer 1</td>
<td>Horizontal</td>
<td>30.9</td>
<td>22</td>
<td>43</td>
<td>1.96</td>
<td>A</td>
<td>46</td>
</tr>
<tr>
<td>Soccer 2</td>
<td>Horizontal</td>
<td>30.4</td>
<td>22</td>
<td>41</td>
<td>1.93</td>
<td>B</td>
<td>38</td>
</tr>
<tr>
<td>Soccer 3</td>
<td>Horizontal</td>
<td>30.9</td>
<td>18</td>
<td>46</td>
<td>2.61</td>
<td>A</td>
<td>46</td>
</tr>
<tr>
<td>Soccer 4</td>
<td>Horizontal</td>
<td>30.3</td>
<td>17</td>
<td>44</td>
<td>2.57</td>
<td>B</td>
<td>38</td>
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<tr>
<td>Spill @ Pl</td>
<td>Horizontal</td>
<td>0.00</td>
<td>0.00</td>
<td>0.04</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
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<tr>
<td>Spill @ Pl</td>
<td>Max Candela (by Fixture)</td>
<td>186</td>
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<td>84</td>
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<tr>
<td>Spill @ Pl</td>
<td>Max Vertical Illuminance</td>
<td>0.00</td>
<td>0.00</td>
<td>0.12</td>
<td>0.00</td>
<td>A,B</td>
<td>84</td>
</tr>
</tbody>
</table>
Arlington County Williamsburg Middle Soccer Fields
Arlington, VA

GRID SUMMARY
Name: Soccer 1
Size: 330' x 198'
Spacing: 30.0' x 30.0'
Height: 3.0' above grade

ILLUMINATION SUMMARY
MAINTAINED HORIZONTAL FOOTCANDLES
Guaranteed Average: 30
Scan Average: 30.88
Maximum: 43
Minimum: 22
Avg / Min: 1.41
Guaranteed Max / Min: 3
Max / Min: 1.96
UG (adjacent pts): 1.82
No. of Points: 77

LUMINAIRE INFORMATION
Color / CRI: 5700K - 75 CRI
Luminaire Output: 63,600 / 63,600 lumens
Total LLF: 1.000
No. of Luminaires: 46
Total Load: 27.96 kW

Lumen Maintenance
Luminaire Type L90 hrs L80 hrs L70 hrs
228 LED 33,000 >42,000 >42,000
216 LED 33,000 >42,000 >42,000

Reported per TM-21-11. See cut sheets for details.

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

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**EQUIPMENT LIST FOR AREAS SHOWN**

<table>
<thead>
<tr>
<th>Pole</th>
<th>Location</th>
<th>Size</th>
<th>Grade</th>
<th>Elevation</th>
<th>Mounting Height</th>
<th>Luminaires</th>
<th>QTY / POLE</th>
<th>THIS GRID</th>
<th>OTHER GRIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S3</td>
<td>80'</td>
<td>-4'</td>
<td>76'</td>
<td>228 / 216 LED</td>
<td>62</td>
<td>12</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>S5-6</td>
<td>80'</td>
<td></td>
<td>80'</td>
<td>216 LED</td>
<td>38</td>
<td>24</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>80'</td>
<td>-4'</td>
<td>76'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td>9</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>S5-S6</td>
<td>80'</td>
<td></td>
<td>80'</td>
<td>216 LED</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>80'</td>
<td>-4'</td>
<td>76'</td>
<td>228 / 216 LED</td>
<td>9</td>
<td>3</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>

**GRID SUMMARY**

**Name:** Soccer 2  
**Size:** 300' x 180'  
**Spacing:** 30.0' x 30.0'  
**Height:** 3.0' above grade

**ILLUMINATION SUMMARY**

**MAINTAINED HORIZONTAL FOOTCANDLES**

<table>
<thead>
<tr>
<th>Enitre Grid</th>
<th>Guaranteed Average: 30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scan Average: 30.41</td>
<td></td>
</tr>
<tr>
<td>Maximum: 41</td>
<td></td>
</tr>
<tr>
<td>Minimum: 22</td>
<td></td>
</tr>
<tr>
<td>Avg / Min: 1.41</td>
<td></td>
</tr>
<tr>
<td>Guaranteed Max / Min: 3</td>
<td></td>
</tr>
<tr>
<td>Max / Min: 1.93</td>
<td></td>
</tr>
<tr>
<td>No. of Points: 60</td>
<td></td>
</tr>
</tbody>
</table>

**GUARANTEED PERFORMANCE:** The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

**FIELD MEASUREMENTS:** Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

**ELECTRICAL SYSTEM REQUIREMENTS:** Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

**INSTALLATION REQUIREMENTS:** Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.
GRID SUMMARY

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Guaranteed Performance.

Electrical System Requirements: Refer to Amperage Chart and/or the "Musco Electrical System Summary" for electrical sizing.

FIELD MEASUREMENTS: Individual field measurements may vary from computer-calculated illuminances and should be taken for verification.

ILLUMINATION SUMMARY

The ILLUMINATION described above is guaranteed per your Musco Guaranteed Performance.

Electrical System Requirements: Refer to Amperage Chart and/or the "Musco Electrical System Summary" for electrical sizing.

FIELD MEASUREMENTS: Individual field measurements may vary from computer-calculated illuminances and should be taken for verification.

No. of Luminaires: 46

UG (adjacent pts): 620.52

228 LED 33,000 on Requirements:

Total Load: 27.96 kW

Maximum: 42

Total LLF: 1.000

Arlington County Williamsburg Middle Soccer Fields
ILLUMINATION SUMMARY

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume +/- 5% normal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

Reported per TM-21-11. See cutsheets for details.
## Equipment List for Areas Shown

<table>
<thead>
<tr>
<th>QTY</th>
<th>LOCATION</th>
<th>SIZE</th>
<th>GRADE</th>
<th>ELEVATION</th>
<th>MOUNTING HEIGHT</th>
<th>LUMINAIRE TYPE</th>
<th>QTY / POLE</th>
<th>THIS GRID</th>
<th>OTHER GRIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>80'</td>
<td>-</td>
<td>80'</td>
<td>228 / 216 LED</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>S2</td>
<td>80'</td>
<td>2'</td>
<td>78'</td>
<td>228 / 216 LED</td>
<td>11</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>S3</td>
<td>80'</td>
<td>-</td>
<td>2'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>S4</td>
<td>80'</td>
<td>-</td>
<td>3'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>S5-S6</td>
<td>80'</td>
<td>1'</td>
<td>81'</td>
<td>216 LED</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

### Grid Summary

- **Name**: Spill @ Pl
- **Spacing**: 30.0'
- **Height**: 8.0' above grade

### Illumination Summary

- **Maintained Max Vertical Footcandles**
  - **Scan Average**: 0.0048
  - **Maximum**: 0.12
  - **Minimum**: 0.00
  - **No. of Points**: 142

### Luminaire Information

- **Color / CRI**: 5700K - 75 CRI
- **Luminaire Output**: 63,600 / 63,600 lumens
- **Total LLF**: 1.000
- **No. of Luminaires**: 84
- **Total Load**: 51.04 kW

### Lumen Maintenance

<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>L90 hrs</th>
<th>L80 hrs</th>
<th>L70 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>228 LED</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td></td>
</tr>
<tr>
<td>216 LED</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td></td>
</tr>
</tbody>
</table>

Reported per TM-21-11. See cutsheets for details.

### Guaranteed Performance

The illumination described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

### Field Measurements

Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

### Electrical System Requirements

Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

### Installation Requirements

Results assume +/- 5% nominal voltage at line side of the driver and structures located within 6 feet (1m) of design locations.
ENGINEERED DESIGN

By: W.VICE  File #166262B  19-Jan-16

SCALE IN FEET 1 : 150

Pole location(s) dimensions are relative to 0,0 reference point(s)

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.
**EQUIPMENT LIST FOR AREAS SHOWN**

<table>
<thead>
<tr>
<th>QTY</th>
<th>LOCATION</th>
<th>SIZE</th>
<th>GRADE</th>
<th>ELEVATION</th>
<th>MOUNTING HEIGHT</th>
<th>LUMINAIRE TYPE</th>
<th>QTY / POLE</th>
<th>THIS GRID</th>
<th>OTHER GRIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>80'</td>
<td></td>
<td></td>
<td></td>
<td>228 / 216 LED</td>
<td>11</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>S2</td>
<td>80'</td>
<td>-2'</td>
<td></td>
<td></td>
<td>228 / 216 LED</td>
<td>21</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>S3</td>
<td>80'</td>
<td>2'</td>
<td></td>
<td></td>
<td>228 / 216 LED</td>
<td>21</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>S5-S6</td>
<td>80'</td>
<td>1'</td>
<td></td>
<td></td>
<td>216 LED</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

**TOTALS**
- 84 QTY
- 84 THIS GRID
- 0 OTHER GRIDS

**GRID SUMMARY**
- Name: 200' Spill
- Spacing: 30.0'
- Height: 3.0' above grade

**ILLUMINATION SUMMARY**
- MAINTAINED HORIZONTAL FOOTCANDLES
  - Scan Average: 0.0001
  - Maximum: 0.00
  - Minimum: 0.00
  - No. of Points: 104

**LUMINAIRE INFORMATION**
- Color / CRI: 5700K - 75 CRI
- Luminaire Output: 63,600 / 63,600 lumens
- Total LLF: 1.000
- No. of Luminaires: 84
- Total Load: 51.04 kW

**Lumen Maintenance**
- L90 hrs
- L80 hrs
- L70 hrs
- 228 LED: >42,000
- 216 LED: >42,000

*Reported per TM-21-11. See cutsheets for details.*

**Guaranteed Performance:** The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

**Field Measurements:** Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

**Electrical System Requirements:** Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

**Installation Requirements:** Results assume +/- 5% normal voltage at line side of the above and structures located within 5 feet (1m) of design locations.
### GRID SUMMARY

**Name:** 200' Spill

**Spacing:** 30.0'

**Height:** 3.0' above grade

### ILLUMINATION SUMMARY

**MAINTAINED MAX VERTICAL FOOTCANDLES**

- **Scan Average:** 0.0009
- **Maximum:** 0.01
- **Minimum:** 0.00
- **No. of Points:** 104

### LUMINAIRE INFORMATION

- **Color / CRI:** 5700K - 75 CRI
- **Luminaire Output:** 63,600 / 63,600 lumens
- **Total LLF:** 1.000
- **No. of Luminaires:** 84
- **Total Load:** 51.04 kW

### Lumen Maintenance

<table>
<thead>
<tr>
<th>Luminaire Type</th>
<th>L90 hrs</th>
<th>L80 hrs</th>
<th>L70 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>228 LED</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td></td>
</tr>
<tr>
<td>216 LED</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td></td>
</tr>
</tbody>
</table>

Reported per TM-21-11. See cutsheets for details.

**Guaranteed Performance:** The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

**Field Measurements:** Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

**Electrical System Requirements:** Refer to Amperage Chart and/or the "Musco Control System Summary" for electrical sizing.

**Installation Requirements:** Results assume +/- 5% normal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

---

**EQUIPMENT LIST FOR AREAS SHOWN**

<table>
<thead>
<tr>
<th>QTY</th>
<th>LOCATION</th>
<th>SIZE</th>
<th>GRADE</th>
<th>ELEVATION</th>
<th>MOUNTING</th>
<th>LUMINAIRE TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>80'</td>
<td>-</td>
<td>80'</td>
<td>228 / 216 LED</td>
<td>11</td>
</tr>
<tr>
<td>1</td>
<td>S2</td>
<td>80'</td>
<td>-2'</td>
<td>78'</td>
<td>228 / 216 LED</td>
<td>11</td>
</tr>
<tr>
<td>1</td>
<td>S3</td>
<td>80'</td>
<td>2'</td>
<td>82'</td>
<td>228 / 216 LED</td>
<td>21</td>
</tr>
<tr>
<td>1</td>
<td>S4</td>
<td>80'</td>
<td>-3'</td>
<td>77'</td>
<td>228 / 216 LED</td>
<td>21</td>
</tr>
<tr>
<td>2</td>
<td>S5-S6</td>
<td>80'</td>
<td>1'</td>
<td>81'</td>
<td>216 LED</td>
<td>10</td>
</tr>
</tbody>
</table>

**TOTALS**

- **No. of Grids:** 74
- **No. of Luminaires:** 84
- **Total Load:** 51.04 kW
Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.
**EQUIPMENT LIST FOR AREAS SHOWN**

<table>
<thead>
<tr>
<th>QTY</th>
<th>LOCATION</th>
<th>SIZE</th>
<th>GRADE</th>
<th>ELEVATION</th>
<th>MOUNTING</th>
<th>HEIGHT</th>
<th>LUMINAIRE TYPE</th>
<th>QTY / POLE</th>
<th>THIS GRID</th>
<th>OTHER GRIDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>80'</td>
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<td>80'</td>
<td></td>
<td></td>
<td>228 / 216 LED</td>
<td>11</td>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>S2</td>
<td>80'</td>
<td>-2'</td>
<td>82'</td>
<td></td>
<td></td>
<td>228 / 216 LED</td>
<td>21</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>S3</td>
<td>80'</td>
<td>2'</td>
<td>82'</td>
<td></td>
<td></td>
<td>228 / 216 LED</td>
<td>21</td>
<td>21</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>S5-S6</td>
<td>80'</td>
<td>1'</td>
<td>81'</td>
<td></td>
<td></td>
<td>216 LED</td>
<td>10</td>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>

**TOTALS**

| QTY | 84         |

**GRID SUMMARY**

- Name: 100' Spill
- Spacing: 30.0'
- Height: 3.0' above grade

**ILLUMINATION SUMMARY**

- **MAINTAINED HORIZONTAL FOOTCANDLES**
  - Scan Average: 0.0200
  - Maximum: 0.13
  - Minimum: 0.00
  - No. of Points: 77

**LUMINAIRE INFORMATION**

- Color / CRI: 5700K - 75 CRI
- Luminaire Output: 63,600 / 63,600 lumens
- Total LLF: 1.000
- No. of Luminaires: 84
- Total Load: 51.04 kW

**Lumen Maintenance**

<table>
<thead>
<tr>
<th>Lumen Type</th>
<th>L90 hrs</th>
<th>L80 hrs</th>
<th>L70 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>228 LED</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td></td>
</tr>
<tr>
<td>216 LED</td>
<td>&gt;42,000</td>
<td>&gt;42,000</td>
<td></td>
</tr>
</tbody>
</table>

Reported per TM-21-11. See cutsheets for details.

**Guaranteed Performance:** The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

**Field Measurements:** Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

**Electrical System Requirements:** Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

**Installation Requirements:** Results assume +/- 5% nominal voltage at line side of the above and structures located within 3 feet (1m) of design locations.
EQUIPMENT LIST FOR AREAS SHOWN

<table>
<thead>
<tr>
<th>Grid</th>
<th>Location</th>
<th>Size</th>
<th>Grade</th>
<th>Elevation</th>
<th>Mounting Height</th>
<th>Luminaires</th>
<th>Qty / Pole</th>
<th>This Grid Qty</th>
<th>Other Grid Qty</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td></td>
<td>80'</td>
<td></td>
<td>0-80'</td>
<td>228 / 216 LED</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td>80'</td>
<td>-2'</td>
<td>78'</td>
<td>228 / 216 LED</td>
<td>11</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td>80'</td>
<td>2'</td>
<td>82'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td>21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S4</td>
<td></td>
<td>80'</td>
<td>-3'</td>
<td>77'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td>21</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>S5-S6</td>
<td></td>
<td>80'</td>
<td>1'</td>
<td>81'</td>
<td>216 LED</td>
<td>10</td>
<td>10</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

TOTALS: 84 Luminaires

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

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Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume +/- 5% nominal voltage at line side of the above and structures located within 5 feet (1.5m) of design locations.
EQUIPMENT LIST FOR AREAS SHOWN

| Pole Location(s) | Dimensions are relative to 0,0 reference point(s) |

GRID SUMMARY

Guaranteed Performance: The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements: Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

**Arlington County Williamsburg Middle Soccer Fields**

**Arlington, VA**

**GRID SUMMARY**

- **Name:** 100' Spill
- **Spacing:** 30.0'
- **Height:** 3.0' above grade

**ILLUMINATION SUMMARY**

- **Maintained Candela (per fixture):**
  - **Scan Average:** 4388.8174
  - **Maximum:** 20571.80
  - **Minimum:** 0.00
  - **No. of Points:** 77

**LUMINAIRE INFORMATION**

- **Color / CRI:** 5700K - 75 CRI
- **Luminaire Output:** 63,600 / 63,600 lumens
- **Total LLF:** 1.000
- **No. of Luminaires:** 84
- **Total Load:** 51.04 kW

**Lumen Maintenance**

- **Luminaire Type**
  - **228 LED**
    - **L90 hrs:** 33,000
    - **L80 hrs:** >42,000
    - **L70 hrs:** >42,000
  - **216 LED**
    - **L90 hrs:** 33,000
    - **L80 hrs:** >42,000
    - **L70 hrs:** >42,000

Reported per TM-21-11. See cutsheets for details.

**Guaranteed Performance:**

- The ILLUMINATION described above is guaranteed per your Musco Warranty document and includes a 0.95 dirt depreciation factor.

- Field Measurements: Individual field measurements may vary from computer-calculated predictions and should be taken in accordance with IESNA LM-5-04.

- Electrical System Requirements: Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

- Installation Requirements: Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.
Arlington County Williamsburg Middle Soccer Fields
Arlington, VA

EQUIPMENT LAYOUT

includes:
- Blanket Grid
- Soccer 1
- Soccer 2

Electrical System Requirements:
Refer to Amperage Draw Chart and/or the "Musco Control System Summary" for electrical sizing.

Installation Requirements:
Results assume +/- 5% nominal voltage at line side of the driver and structures located within 3 feet (1m) of design locations.

EQUIPMENT LIST FOR AREAS SHOWN

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>SIZE</th>
<th>GRADE</th>
<th>ELEVATION</th>
<th>MOUNTING HEIGHT</th>
<th>LUMINAIRE TYPE</th>
<th>QTY / POLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>80'</td>
<td>-80'</td>
<td>228 / 216 LED</td>
<td>11</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>80'</td>
<td>-2'</td>
<td>78'</td>
<td>228 / 216 LED</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>80'</td>
<td>2'</td>
<td>82'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>80'</td>
<td>-3'</td>
<td>77'</td>
<td>228 / 216 LED</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>S5-S6</td>
<td>80'</td>
<td>-80'</td>
<td>216 LED</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTALS: 84

SINGLE LUMINAIRE AMPERAGE DRAW CHART

<table>
<thead>
<tr>
<th>Single Phase Voltage</th>
<th>208 (60)</th>
<th>220 (60)</th>
<th>240 (60)</th>
<th>277 (60)</th>
<th>347 (60)</th>
<th>380 (60)</th>
<th>480 (60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>228 LED</td>
<td>3.9</td>
<td>3.7</td>
<td>3.4</td>
<td>3.0</td>
<td>2.4</td>
<td>1.7</td>
<td></td>
</tr>
<tr>
<td>216 LED</td>
<td>3.8</td>
<td>3.6</td>
<td>3.3</td>
<td>2.8</td>
<td>2.3</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>
Map indicates the maximum candela an observer would see when facing the brightest light source from any direction.

A well-designed lighting system controls light to prevent excessive glare to fields of vision with minimal destructive off-site glare.
The .02 fc down the property line were due to a neighboring property with existing LED lights attached to the back fence. In addition, the .02 fc and 1.5 fc respectively along the street and the southernmost border of this illustration were due to existing street lighting.
The following represents the addition of the property line spill light levels from the Photometric Plan using 80’ poles at 30fc horizontal average on the playing surface combined with the existing Ambient Light Levels Taken on February 29th, 2016 by Joe Forche, Stephen Baker, and members of WFWG using a Gossen Mavolux Light Meter 5032C (Serial #3C15706) Calibrated November 6th, 2015. The figures illustrate combined maximum horizontal spill light at the property line.
Joint Statement of Williamsburg School Neighbors

We, the undersigned neighbors of Williamsburg Middle School (WMS), strongly oppose installation of lights on the school’s athletic fields.

Our neighborhood is entirely residential; it contains no stores or commercial buildings and no street network where traffic exists at all hours. Our lots are zoned R-10 to R-20, creating a presumption that the neighborhood will not be urbanized.

The WMS fields have never been lit; based on the County’s zoning policies, neighbors who purchased, rent or built nearby homes did so with the reasonable expectation of enjoying freedom from noise and light pollution during evening hours and from bursts of heavy night-time traffic. No other exclusively residential neighborhood in the County has been subject to the imposition of massive 70-90 foot tall lights.

Lighting of the WMS soccer fields would result in glare affecting virtually every near neighbor’s house and yard. Noise - including shouts, whistles, cheers and protests by players, coaches, referees and spectators - would be clearly audible on patios, porches, decks, lawns and through windows of nearby homes. This is not speculation; we have intimate knowledge of the noise generated by daytime soccer games and with glare from newly installed lights on the WMS basketball court. The ability of our families to get a decent night’s rest, the sight of a clear night sky and the birds and other wildlife that inhabit our neighborhood are priceless to us.

The sound of car doors slamming, engines starting, horns honking and the glare of head and taillights flashing as teams and fans come and go will disturb families throughout the neighborhood especially in spring and fall when leaves are sparse on trees along the edges of the WMS property.

Arlington currently has 15 lighted rectangular fields and an additional 19 lighted diamond fields configured for baseball/softball that could also be used for soccer, lacrosse or ultimate Frisbee practice. These fields can accommodate many times the number of adult soccer players from Arlington who are demanding additional space for night time practice and play. As part of the current Public Spaces Master Planning (PSMP) process, information has reportedly been provided regarding additional locations where lights could be installed. If there is a demonstrated need for more lighted fields, the PSMP planning process should seek to identify, in a carefully researched and fully transparent manner, the best locations to add capacity and precede any action to light the WMS fields by default.

There is no compelling reason for Arlington to install lights on the WMS fields, in the process doing great damage to a neighborhood that will already be subject to significantly increased traffic and noise and light pollution as a result of the 2015 opening of the new elementary school and the possible expansion of WMS. We urge you to join us in saying no to field lights at WMS.

Signed by:

No. 37th Street Abutting Neighbors

Joseph Delogu
Nancy Delogu
5310 No. 37th Street
Arlington, VA 22207

Ed Kinsella
Megan Kinsella
5320 No. 37th Street
Arlington, VA 22207

Brian Nagoski
Lara Nagoski
5330 No. 37th Street
Arlington, VA 22207
### No. Jefferson Street (3600 Block) Abutting and Near Neighbors

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beverly Groom</td>
<td>Arlington, VA 22207</td>
<td>Gail Harrison</td>
<td>Arlington, VA 22207</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Judy Hadden</td>
<td>3600 No. Jefferson St.</td>
</tr>
<tr>
<td>Mary Margaret Pipkin</td>
<td>3609 No. Jefferson St.</td>
<td>Newell Highsmith</td>
<td>Arlington, VA 22207</td>
</tr>
<tr>
<td>Robert Boisture</td>
<td>Arlington, VA 22207</td>
<td>Dian Heim</td>
<td></td>
</tr>
</tbody>
</table>

### No. Kenilworth Street Abutting and Near Neighbors

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roy Gamse</td>
<td>3615 N. Kenilworth St.</td>
<td>Oliver McDaniel</td>
<td>3607 N. Kenilworth St.</td>
</tr>
<tr>
<td>Joyce Gamse</td>
<td>Arlington, VA 22207</td>
<td>Janice McDaniel</td>
<td>Arlington, VA 22207</td>
</tr>
<tr>
<td>Laura Gamse</td>
<td></td>
<td>Andrew McDaniel</td>
<td>3601 N. Kenilworth St.</td>
</tr>
<tr>
<td>Michael Anderson</td>
<td>3621 N. Kenilworth St.</td>
<td>Paul Kemp</td>
<td></td>
</tr>
<tr>
<td>Kelly Anderson</td>
<td>Arlington, VA 22207</td>
<td>Margaret Kemp</td>
<td></td>
</tr>
</tbody>
</table>

### No. 36th Street Across-the-Street Neighbors

<table>
<thead>
<tr>
<th>Name</th>
<th>Address</th>
<th>Name</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atsushi Yuzawa</td>
<td>5232 N. 36th Street</td>
<td>Susan Trapasso</td>
<td>5340 N. 36th Street</td>
</tr>
<tr>
<td>Kelly Yuzawa</td>
<td>Arlington, VA 22207</td>
<td>Maeve Dwyer</td>
<td>Arlington, VA 22207</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lincoln Oliphant</td>
<td>5300 N. 36th St.</td>
<td>Paul Horowitz</td>
<td>5228 N. 36th St.</td>
</tr>
<tr>
<td>Donna Oliphant</td>
<td>Arlington, VA 22207</td>
<td>Sandra Horowitz</td>
<td>Arlington, VA 22207</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Alicia Kabiri</td>
<td>5306 N. 36th St.</td>
</tr>
<tr>
<td>David Fahrenkrug</td>
<td>5401 Williamsburg Blvd.</td>
<td>Jorge Sandoval*</td>
<td>5318 N. 36th St.</td>
</tr>
<tr>
<td>Darlene Fahrenkrug</td>
<td>Arlington, VA 22207</td>
<td>Bert Braley</td>
<td>5324 N. 36th St.</td>
</tr>
<tr>
<td></td>
<td>(Backyard faces N. 36th)</td>
<td>Linda Braley</td>
<td></td>
</tr>
</tbody>
</table>
No. Jefferson Street (3500) Across-the-Street and Near Neighbors

John Kirby
Liz Kirby
3500 No. Jefferson St.
Arlington, VA 22207

Namita Singh
Ariel Singh
3508 N. Jefferson St
Arlington, VA 22207

Hoyun Kim*
James Piehl
3508 N. Jefferson St
Arlington, VA 22207

J. Brady Dugan
Benjamin Dugan
Erin Grace
3505 N. Jefferson St
Arlington, VA 22207

Ira Rubenstein
Juliana Rubenstein
3509 N. Jefferson St.
Arlington, VA 22207

Note asterisk (*) identifies neighbors who oppose lights but moved into the neighborhood after the petition was circulated.