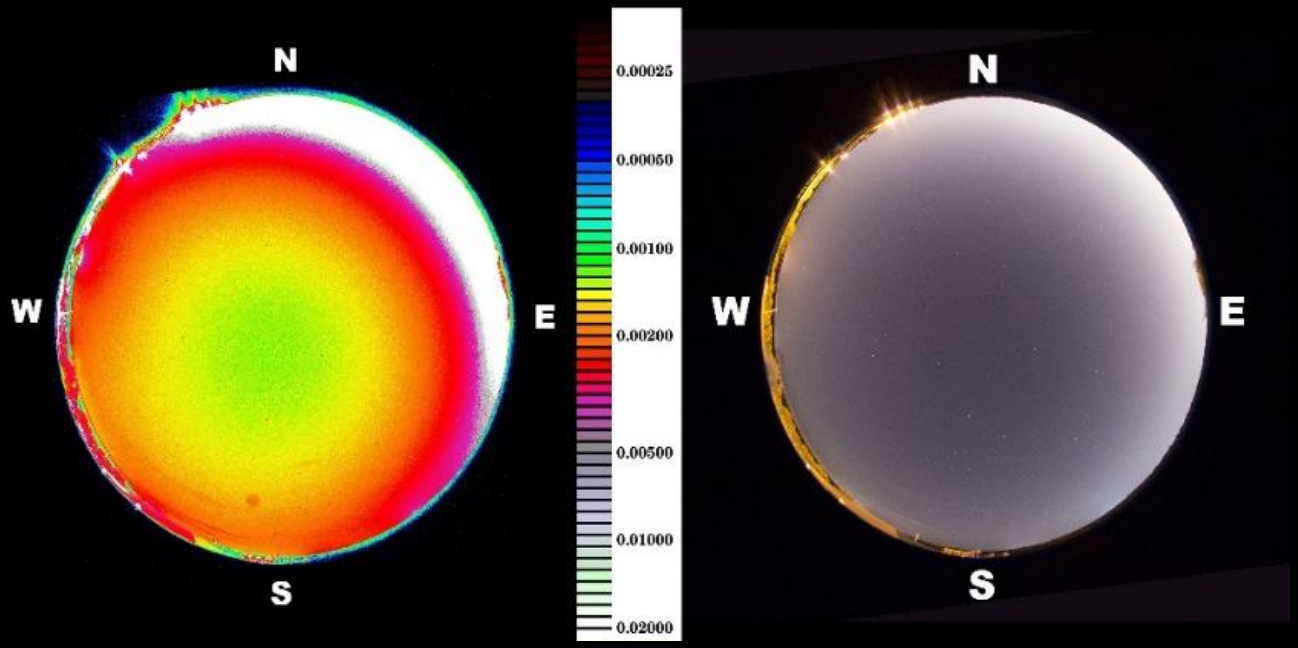
Assessing than Mitigating

Skyglow Measurements to Lighting Ordinances



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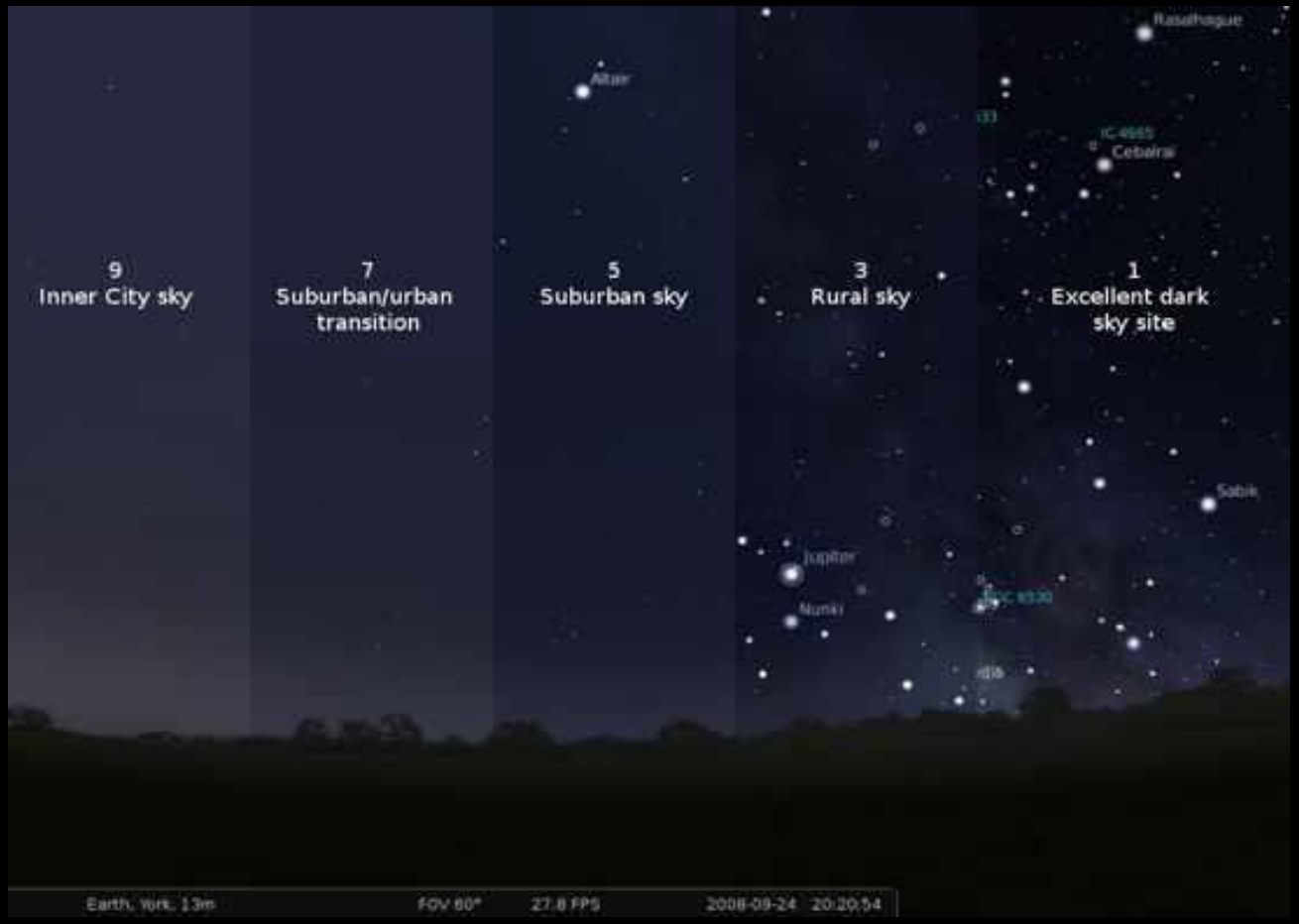
Outline

- Assessing
  - Skyglow metrics and measurement
  - Evaluation and interpretation
- Mitigating
  - Writing and enforcing an ordinance
  - The future of outdoor lighting

Assessing

Skyglow Metrics

- Zenith Luminance
- Bortle Scale

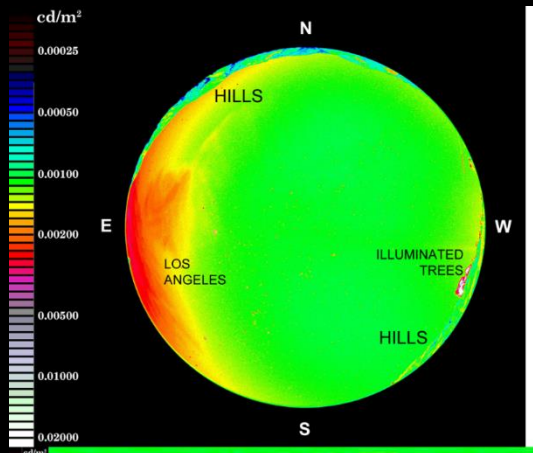


Measurement Process

- Sky quality meter
  - SQM
  - SQM-L
- Photography
- Spectral Measurements

- Calibration
- Image assembly

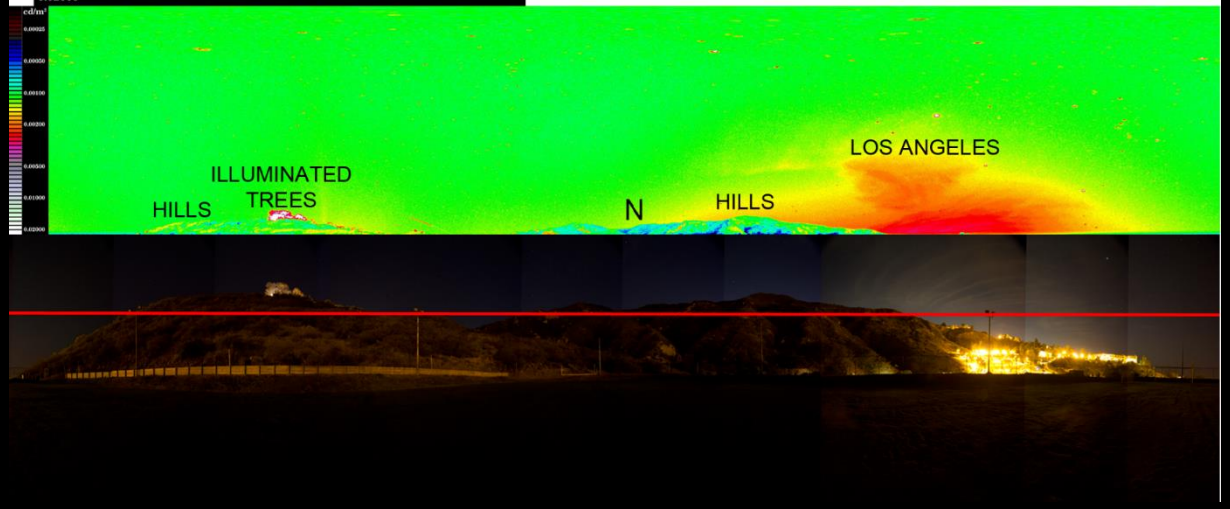
Measurement Examples



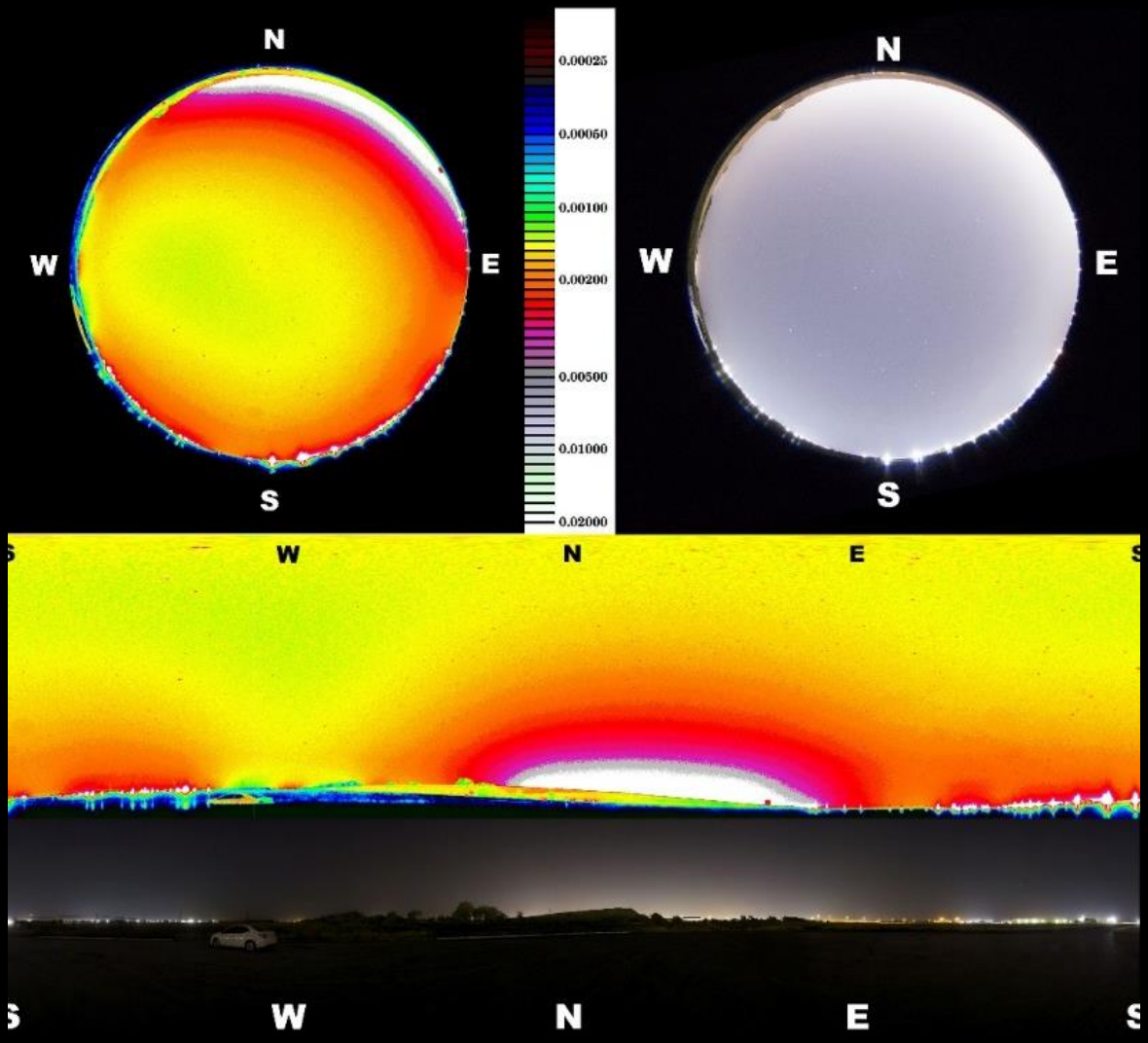
Location 4

Intramural field (sports lights **OFF**)

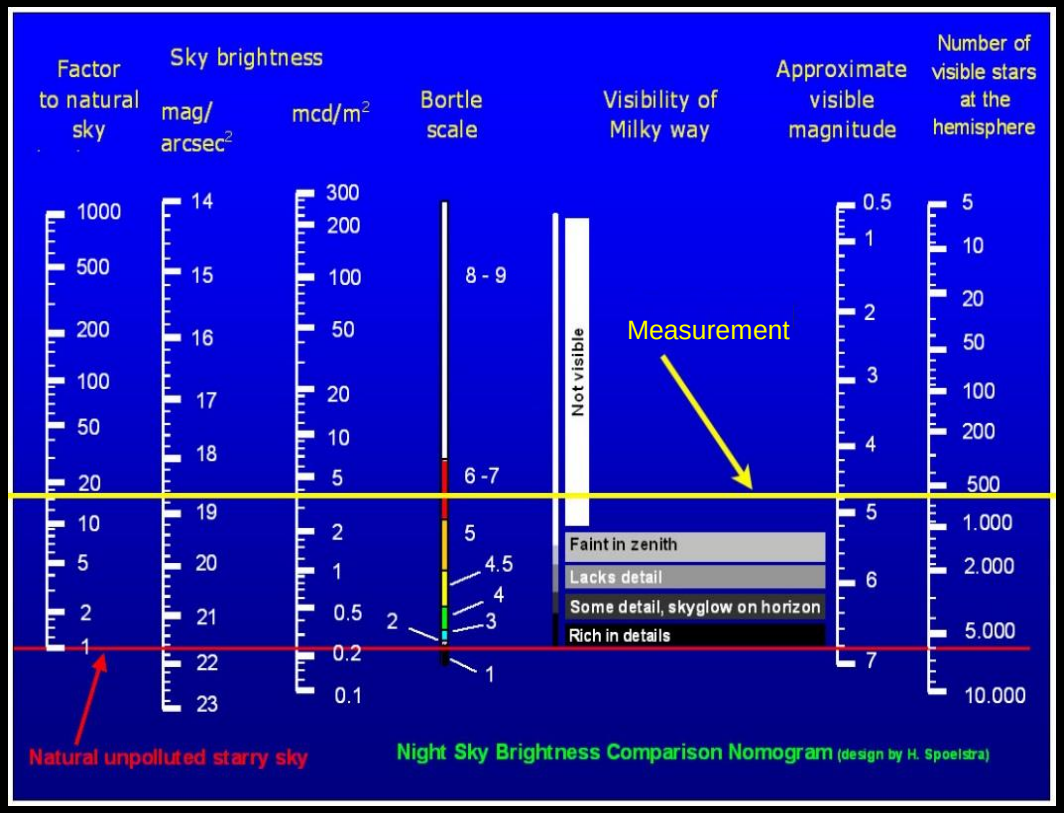
Latitude N34.0463
Longitude W118.7116
2014 Jan 2
22:37:27 PST
Cloud cover: 10%
Relative humidity: 50%
SQM-L: 0.002581 cd/m^2 (19.32 mag/arcsec^2)
Image ID: IMG_9071.CR2

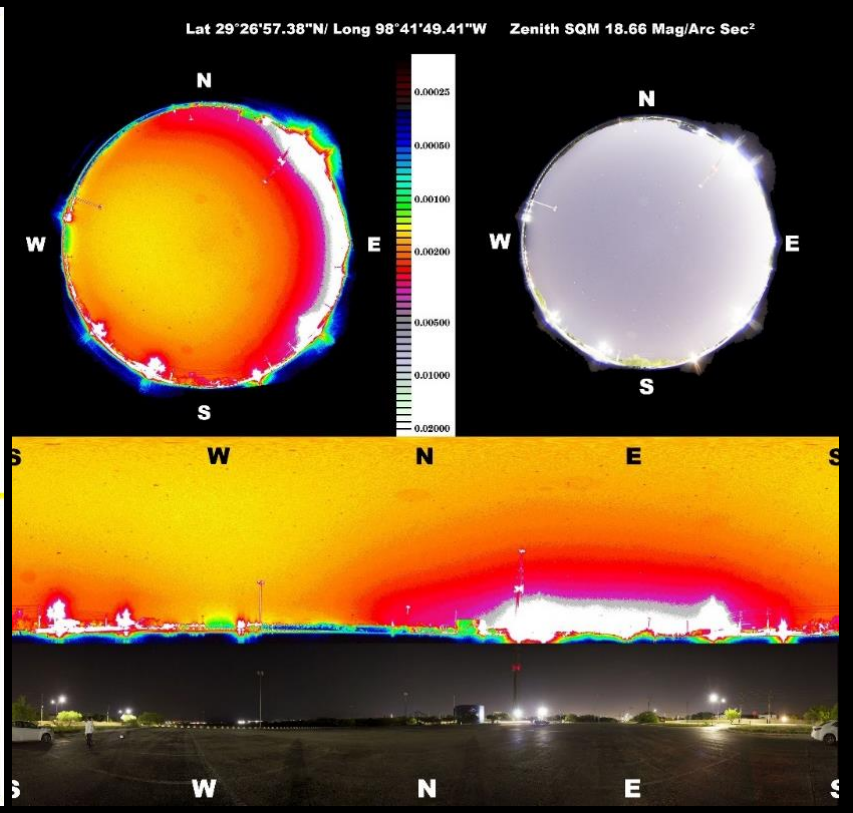


Measurement Examples



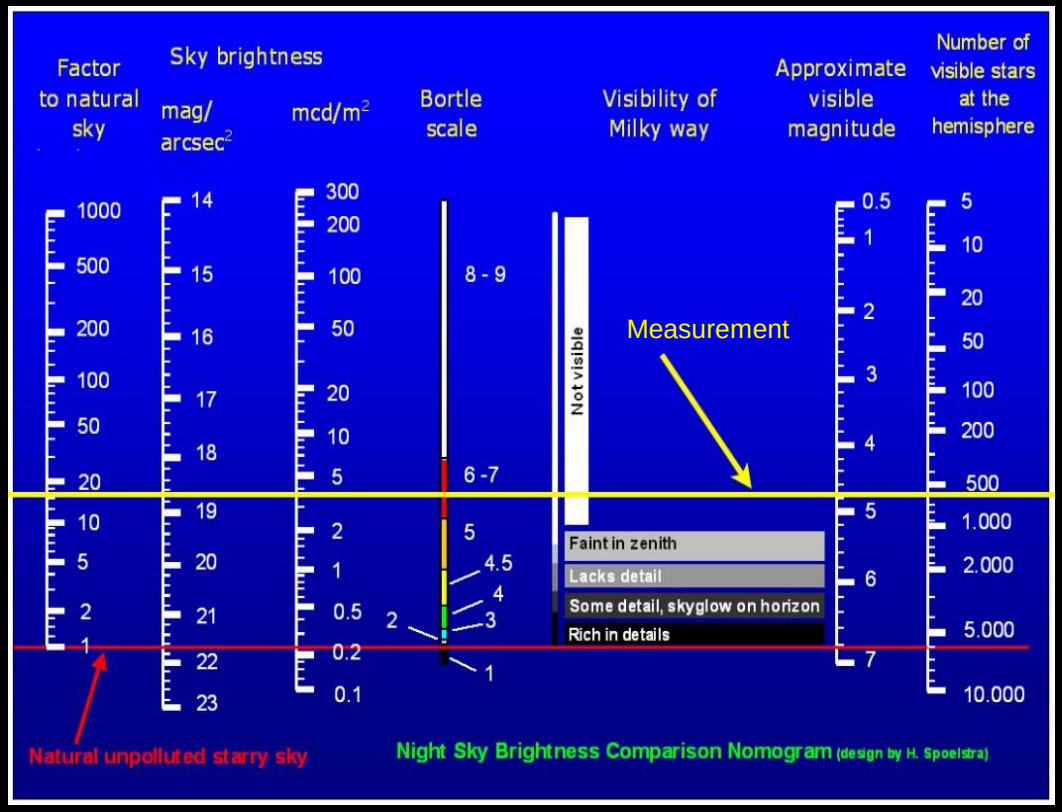
Evaluation & Interpretation





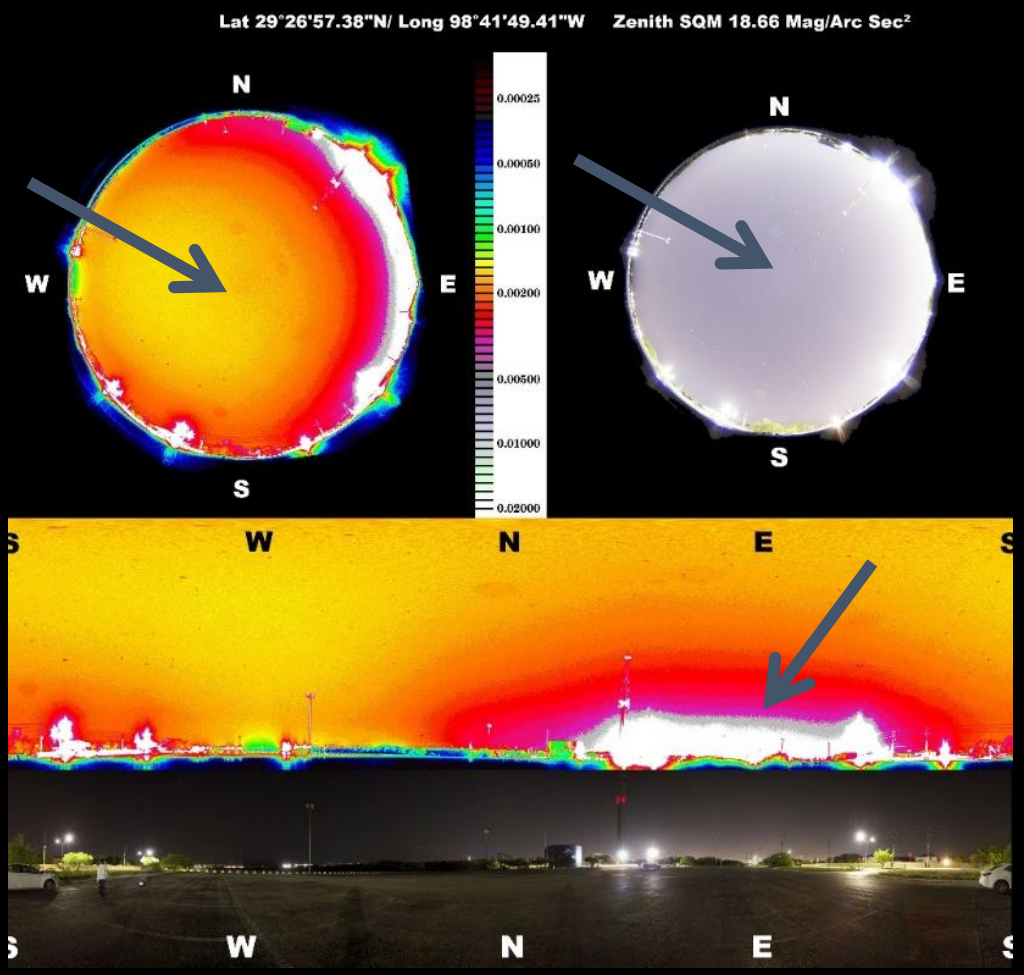
Evaluation & Interpretation

- Overall Quality
- Relative Quality



Evaluation & Interpretation

- Skydome brightness
- Horizon brightening
- Glare sources

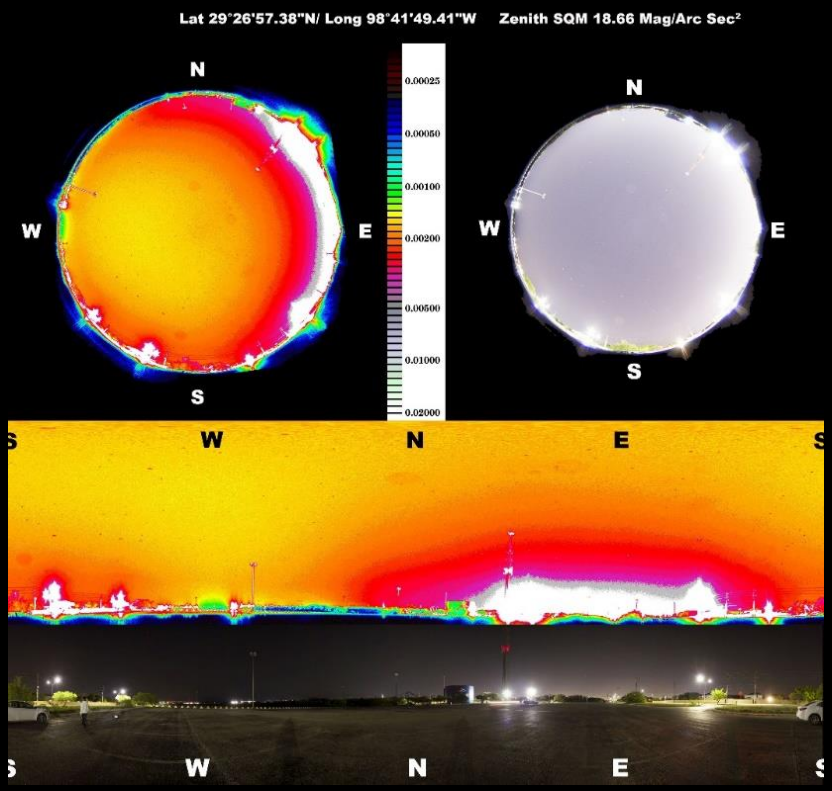


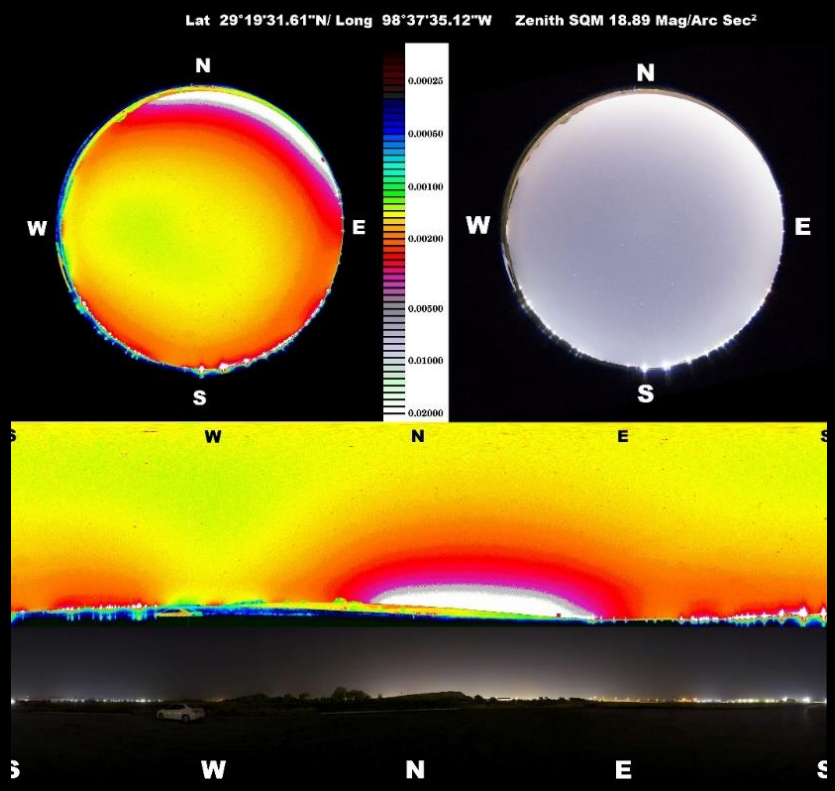
Limitations

- Geography and Adjacencies

Limitations

- Zenith Luminance

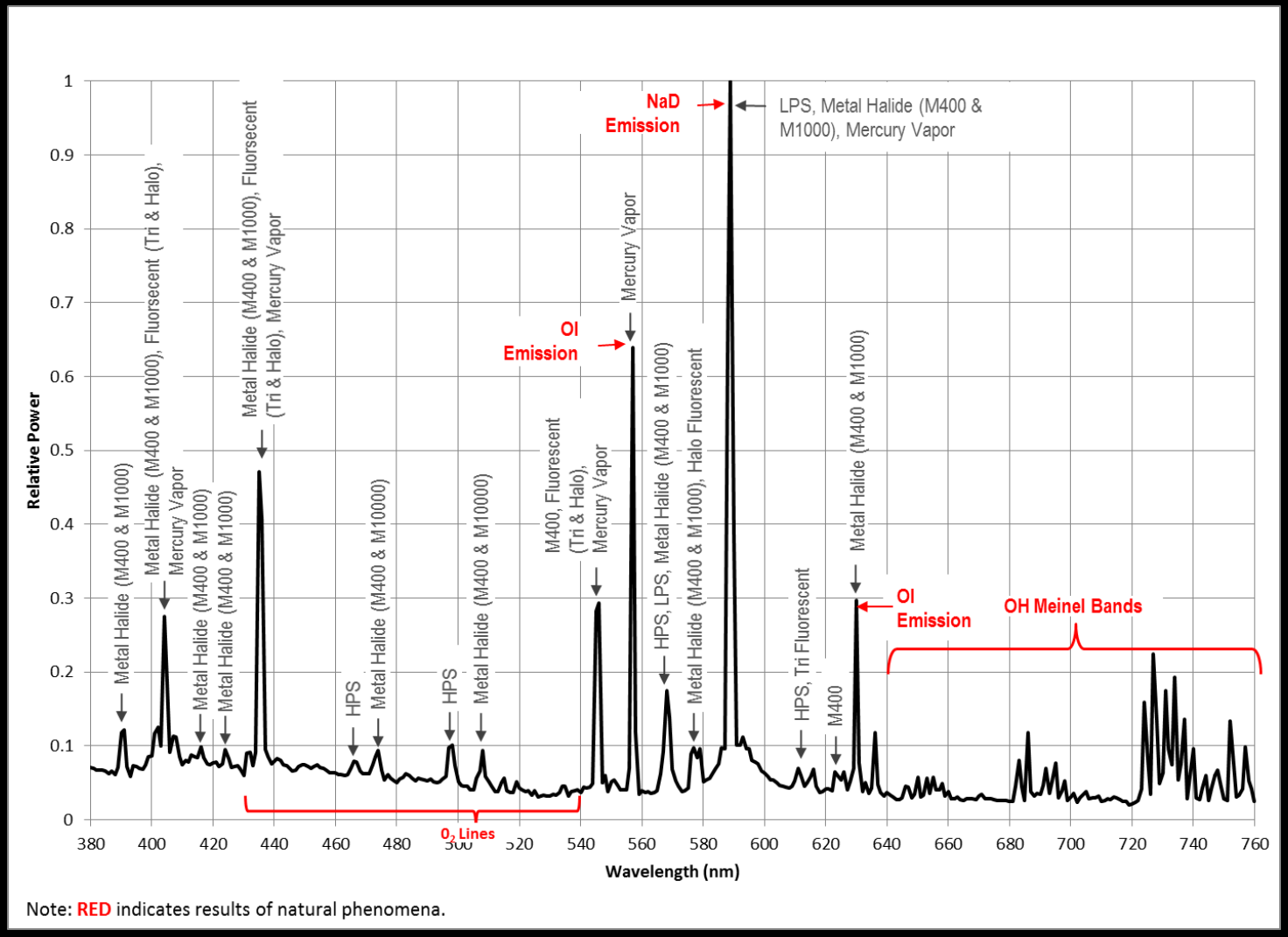




Limitations

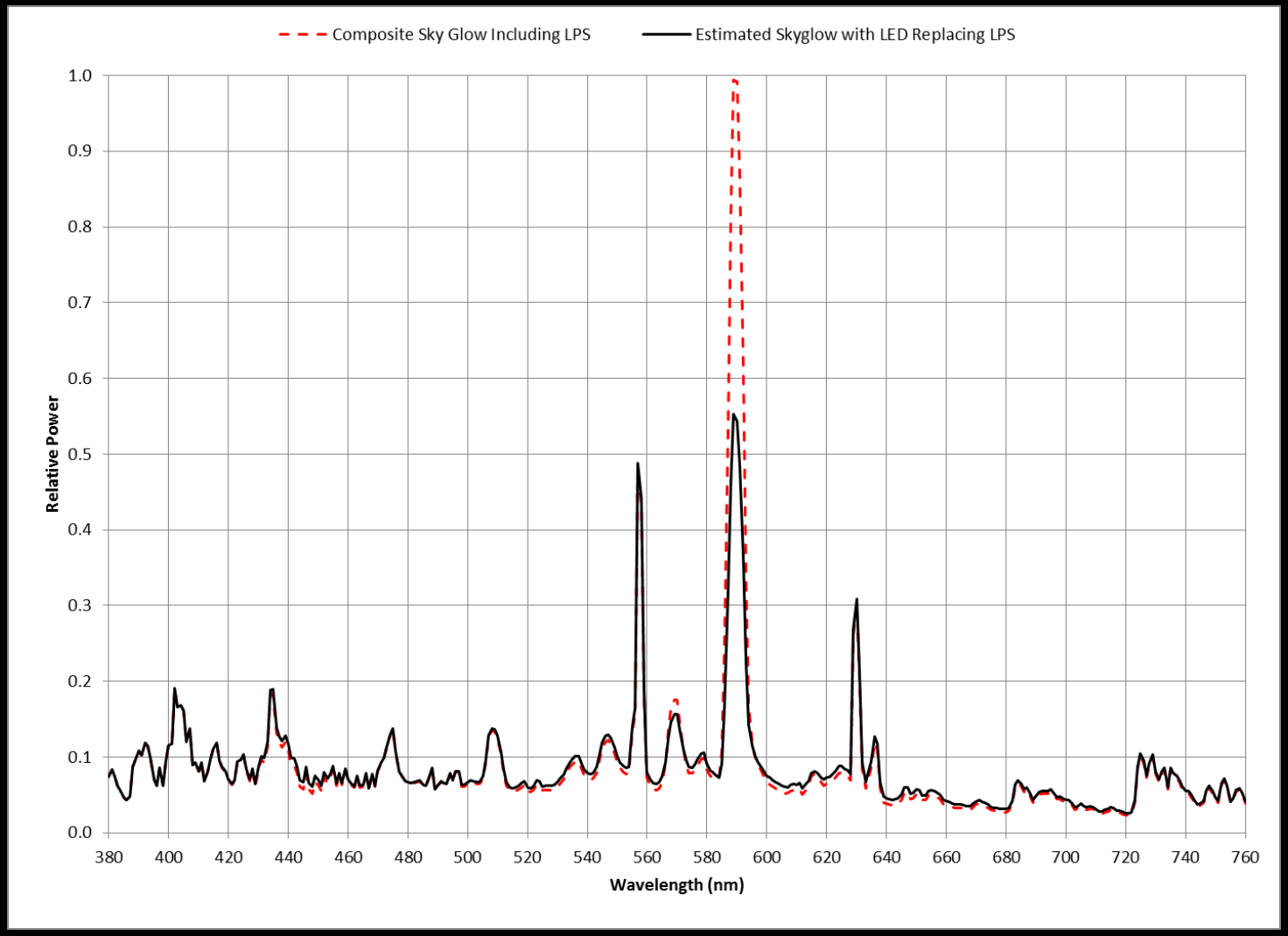
Class	Title	NELM	Description
1	Excellent dark-sky site	7.6–8.0	The zodiacal light is visible and colorful; the gegenschein is visible; the zodiacal band is visible; airglow is readily visible; the Scorpius and Sagittarius regions of the Milky Way cast obvious shadows; many Messier and globular clusters are naked-eye objects; M33 is a direct vision naked-eye object; M33 is a direct vision naked-eye object; limiting magnitude with 12.5" reflector is 17.5 (with effort).
2	Typical truly dark site	7.1–7.5	The zodiacal light is distinctly yellowish and bright enough to cast shadows at dusk and dawn; airglow may be weakly visible near horizon; clouds are only visible as dark holes against the sky; surroundings are barely visible silhouetted against the sky; the summer Milky Way is highly structured; many Messier objects and globular clusters are naked-eye objects; M33 is easily seen with naked eye; limiting magnitude with 12.5" reflector is 16.5.
3	Rural sky	6.6–7.0	The zodiacal light is striking in spring and autumn, and color is still visible; some light pollution evident at the horizon; clouds are illuminated near the horizon, dark overhead; nearer surroundings are vaguely visible; the summer Milky Way still appears complex; M15, M4, M5, and M22 are naked-eye objects; M33 is easily visible with averted vision; limiting magnitude with 12.5" reflector is 16.
4	Rural/suburban transition	6.1–6.5	The zodiacal light is still visible, but does not extend halfway to the zenith at dusk or dawn; light pollution domes visible in several directions; clouds are illuminated in the directions of the light sources, dark overhead; surroundings are clearly visible, even at a distance; the Milky Way well above the horizon is still impressive, but lacks detail; M33 is a difficult averted vision object, only visible when high in the sky; limiting magnitude with 12.5" reflector is 15.5.
5	Suburban sky	5.6–6.0	Only hints of zodiacal light are seen on the best nights in autumn and spring; light pollution is visible in most, if not all, directions; clouds are noticeably brighter than the sky; the Milky Way is very weak or invisible near the horizon, and looks washed out overhead; limiting magnitude with 12.5" reflector is 15.
6	Bright suburban sky	5.1-5.5	The zodiacal light is invisible; light pollution makes the sky within 35° of the horizon glows grayish white; clouds anywhere in the sky appear fairly bright; surroundings are easily visible; the Milky Way is only visible near the zenith; M33 is not visible, M31 is modestly apparent; limiting magnitude with 12.5" reflector is 14.5.
7	Suburban/urban transition	4.6–5.0	Light pollution makes the entire sky light gray; strong light sources are evident in all directions; clouds are brightly lit; the Milky Way is invisible; M31 and M44 may be glimpsed, but with no detail; through a telescope, the brightest Messier objects are pale ghosts of their true selves; limiting magnitude with 12.5" reflector is 14.
8	City sky	4.1–4.5	The sky is light gray or orange - one can easily read; stars forming familiar constellation patterns may be weak or invisible; M31 and M44 are barely glimpsed by an experienced observer on good nights; even with a telescope, only bright Messier objects can be detected; limiting magnitude with 12.5" reflector is 13.
9	Inner-city sky	4	The sky is brilliantly lit; many stars forming constellations are invisible and many fainter constellations are invisible; aside from the Pleiades, no Messier object is visible to the naked eye; the only objects to observe are the Moon, the planets, and a few of the brightest star clusters

Spectral Information



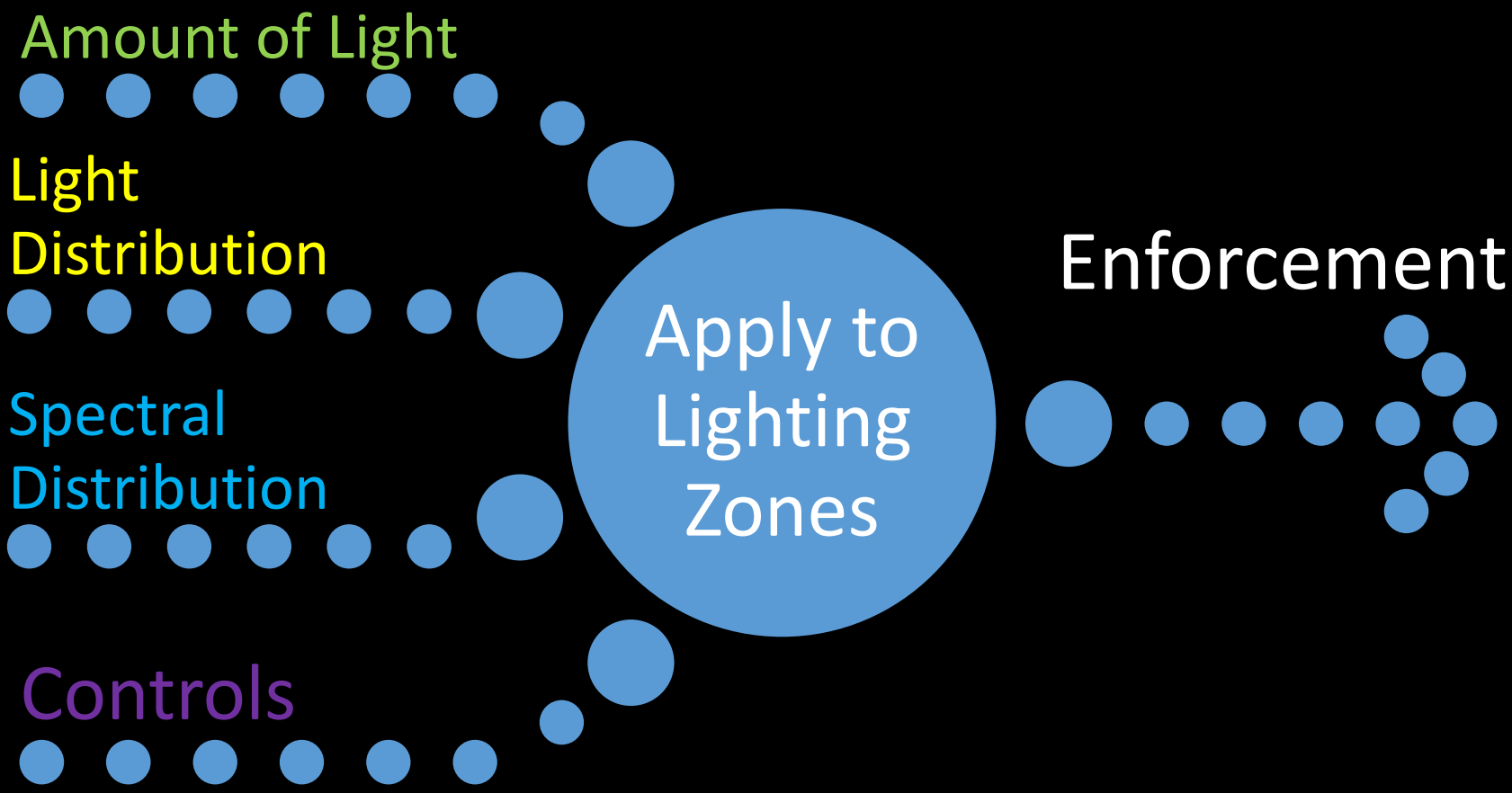
Note: **RED** indicates results of natural phenomena.

Spectral Information



Mitigating

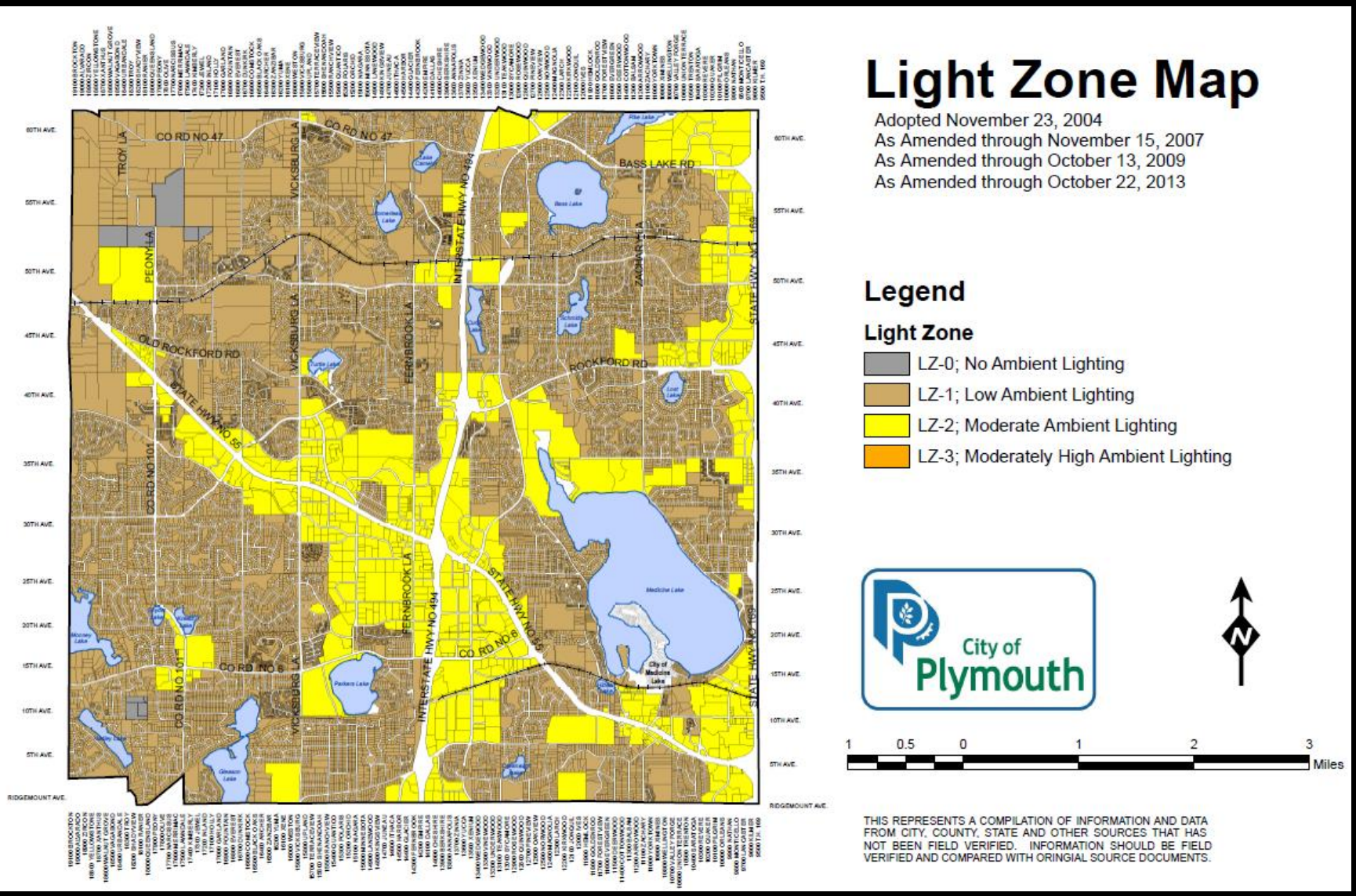
Ordinance Components



Lighting Zones (LZ)

	LZ-0	LZ-1	LZ-2	LZ-3	LZ-4
Description	Permanent lighting is not expected.	Low ambient lighting levels.	Moderate ambient lighting levels.	Moderately high ambient lighting levels.	Very high ambient lighting levels.
Applicable Land Use	Natural Tier.	Country Tier, Agribusiness Tier, and Rural Estate Tier.	Suburban Tier, General Urban Tier, Regional Center, and Civic Center.	Urban Core Tier, Specialized Center, and Mixed Use Center.	Not applicable.
Default Designations	Default for undeveloped rural areas.	Default for rural and low-density residential.	Default for light commercial business districts or mixed-use districts.	Default for large cities' business or downtown districts.	Not a default zone.
Examples	Examples: Parks; natural areas; recreational areas.	Commercial Examples: Small-scale farms or ranches; small neighborhood stores; commercial uses to serve low density rural estate neighborhoods. Residential Examples: Large-tract detached single family housing.	Commercial Examples: Detached retail services; walkable retail services, "big box" retail; office complexes; light manufacturing. Residential Examples: Small and large attached and detached single-family housing; multifamily housing; condominiums.	Commercial Examples: Mixed use blocks and buildings; attached hotels, office and retail/services in mid to high rise buildings. Residential examples: High-density attached multi-family apartment buildings, lofts, and condos.	Not applicable.

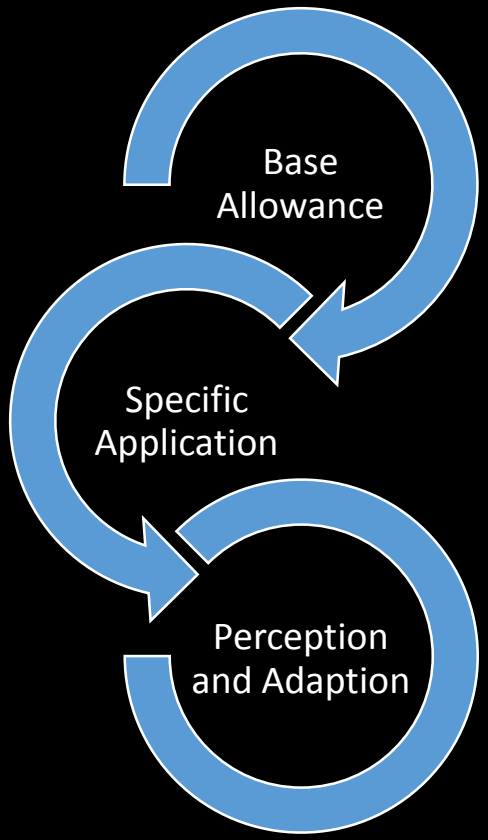
LZ per Land Use Zones



LZ per Critical Areas or Tasks

Amount of Light

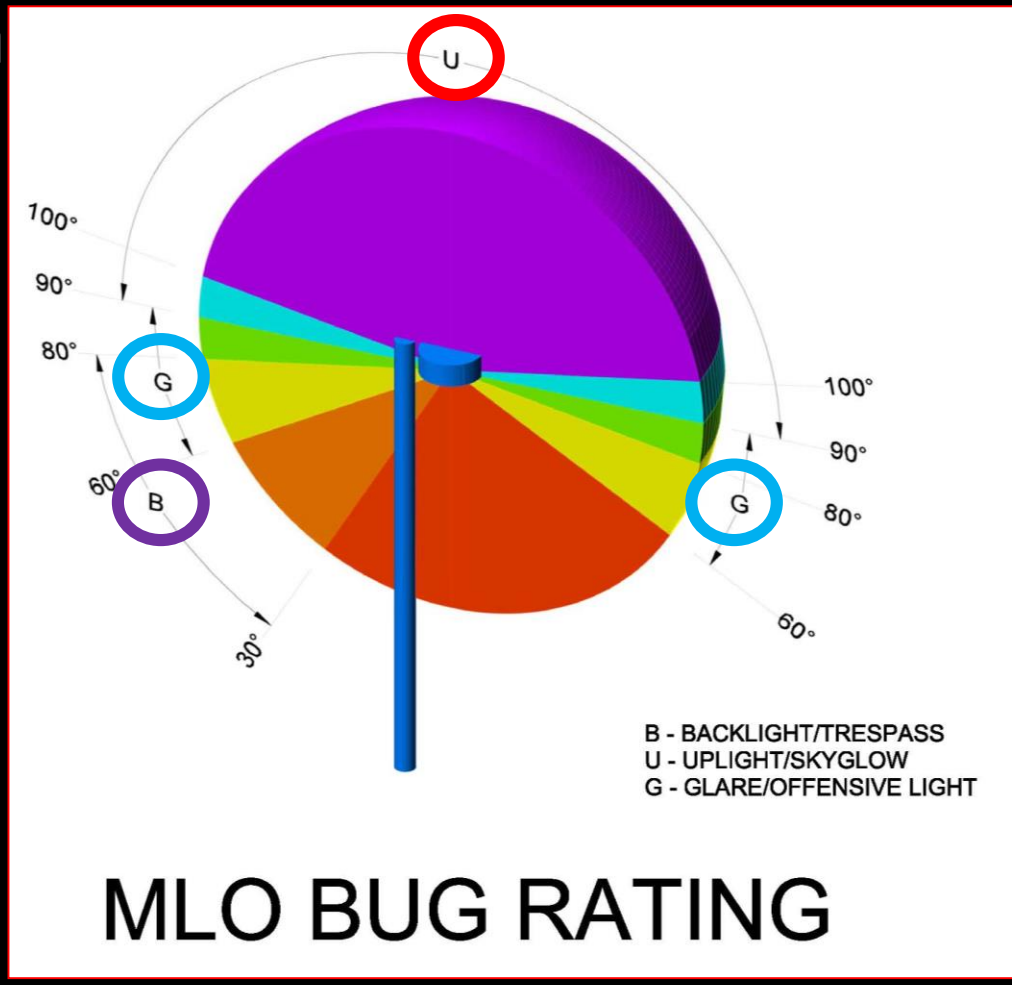
LZ-0	LZ-1	LZ-2	LZ-3	LZ-4
Base Allowance				
0.5 lumens per SF of Hardscape	1.25 lumens per SF of Hardscape	2.5 lumens per SF of Hardscape	5.0 lumens per SF of Hardscape	7.5 lumens per SF of Hardscape



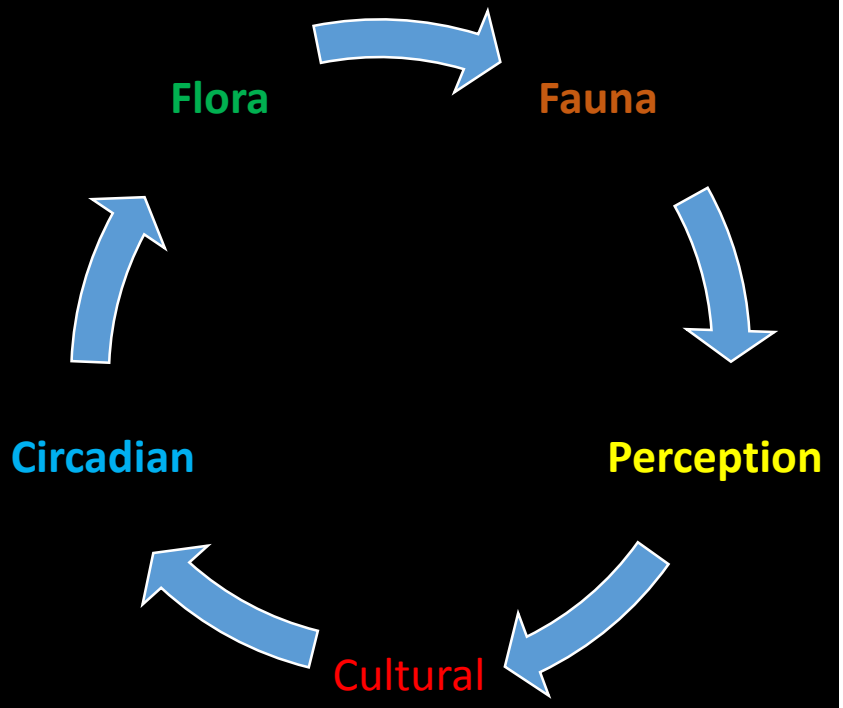
	LZ 0	LZ 1	LZ 2	LZ 3	LZ 4
Additional allowances for sales and service facilities. No more than two additional allowances per site, Use it or Lose it.					
Outdoor Sales Lots. This allowance is lumens per square foot of uncovered sales lots used exclusively for the display of vehicles or other merchandise for sale, and may not include driveways, parking or other non sales areas. To use this allowance, luminaires must be within 2 mounting heights of sales lot area.	0	4 lumens per square foot	8 lumens per square foot	16 lumens per square foot	16 lumens per square foot
Outdoor Sales Frontage. This allowance is for lineal feet of sales frontage immediately adjacent to the principal viewing location(s) and unobstructed for its viewing length. A corner sales lot may include two adjacent sides provided that a different principal viewing location exists for each side. In order to use this allowance, luminaires must be located between the principal viewing location and the frontage outdoor sales area	0	0	1,000 per LF	1,500 per LF	2,000 per LF
Drive Up Windows. In order to use this allowance, luminaires must be within 20 feet horizontal distance of the center of the window.	0	2,000 lumens per drive-up window	4,000 lumens per drive-up window	8,000 lumens per drive-up window	8,000 lumens per drive-up window
Vehicle Service Station. This allowance is lumens per installed fuel pump.	0	4,000 lumens per pump (based on 5 fc horiz)	8,000 lumens per pump (based on 10 fc horiz)	16,000 lumens per pump (based on 20 fc horiz)	24,000 lumens per pump (based on 20 fc horiz)

Distribution of Light

- Backlight, Uplight, Glare (BUG)
- Location and Orientation
- Downlight reflection



Spectral Characteristics - Consequences



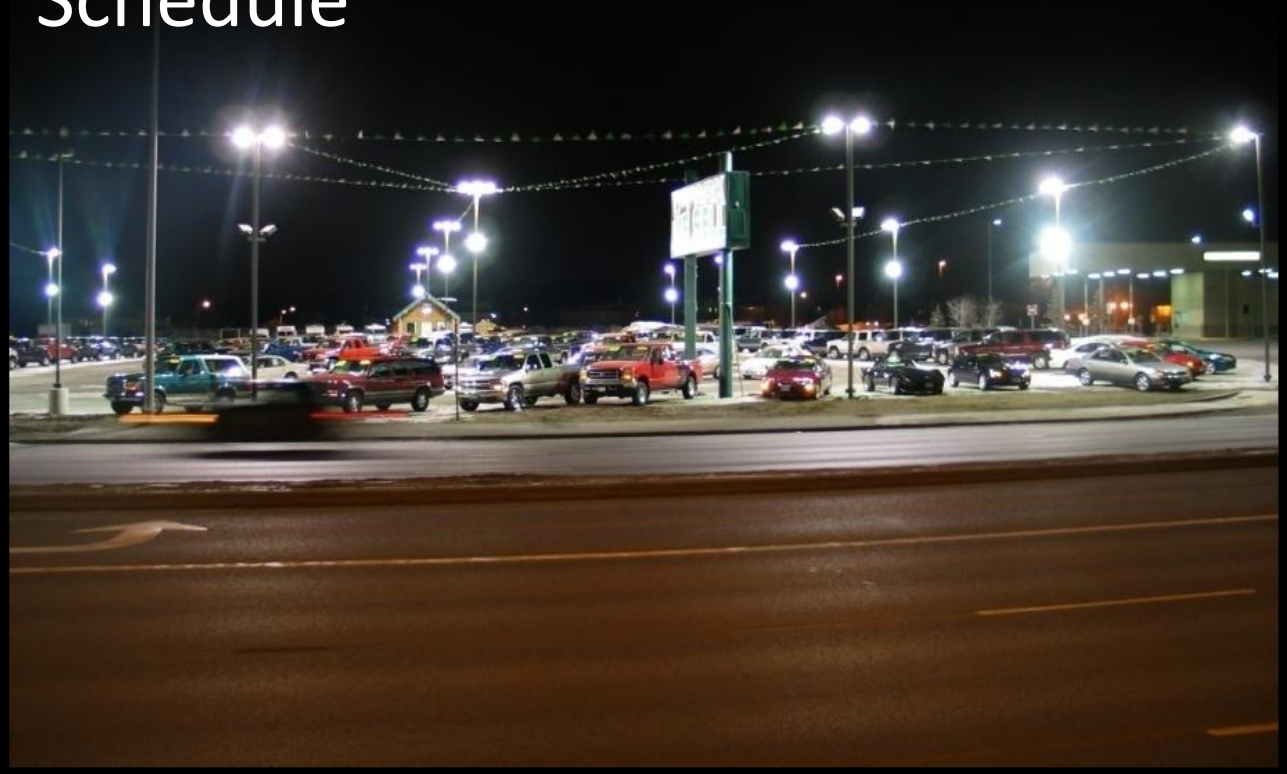
Temperature	Source
1,700 K	Match flame, low pressure sodium lamps (LPS/SOX)
1,850 K	Candle flame, sunset/sunrise
2,700–3,300 K	Incandescent lamps
3,000 K	Soft (or Warm) White compact fluorescent lamps
3,200 K	Studio lamps, photofloods, etc.
3,350 K	Studio "CP" light
4,100–4,150 K	Moonlight[2]
5,000 K	Horizon daylight
5,000 K	Tubular fluorescent lamps or cool white/daylight compact fluorescent lamps (CFL)
5,500–6,000 K	Vertical daylight, electronic flash
6,200 K	Xenon short-arc lamp[3]
6,500 K	Daylight, overcast
6,500–10,500 K	LCD or CRT screen
15,000–27,000 K	Clear blue poleward sky
These temperatures are merely characteristic; considerable variation may be present.	

Lighting Controls

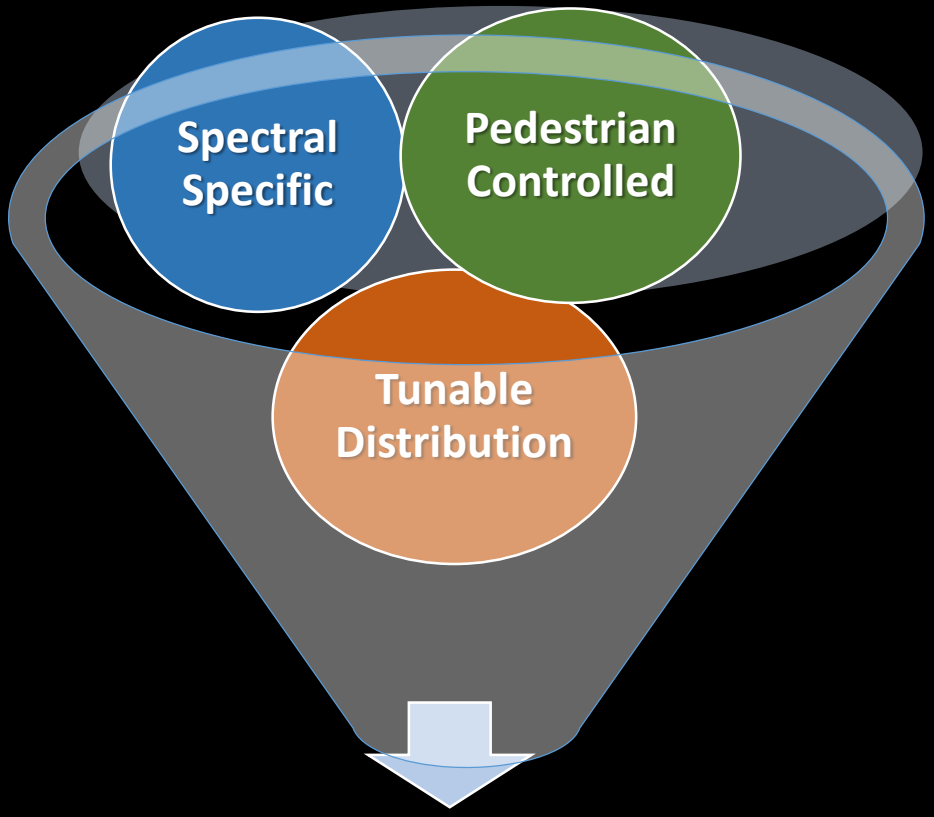
Dimming

Curfew Schedule

Spectral Tuning



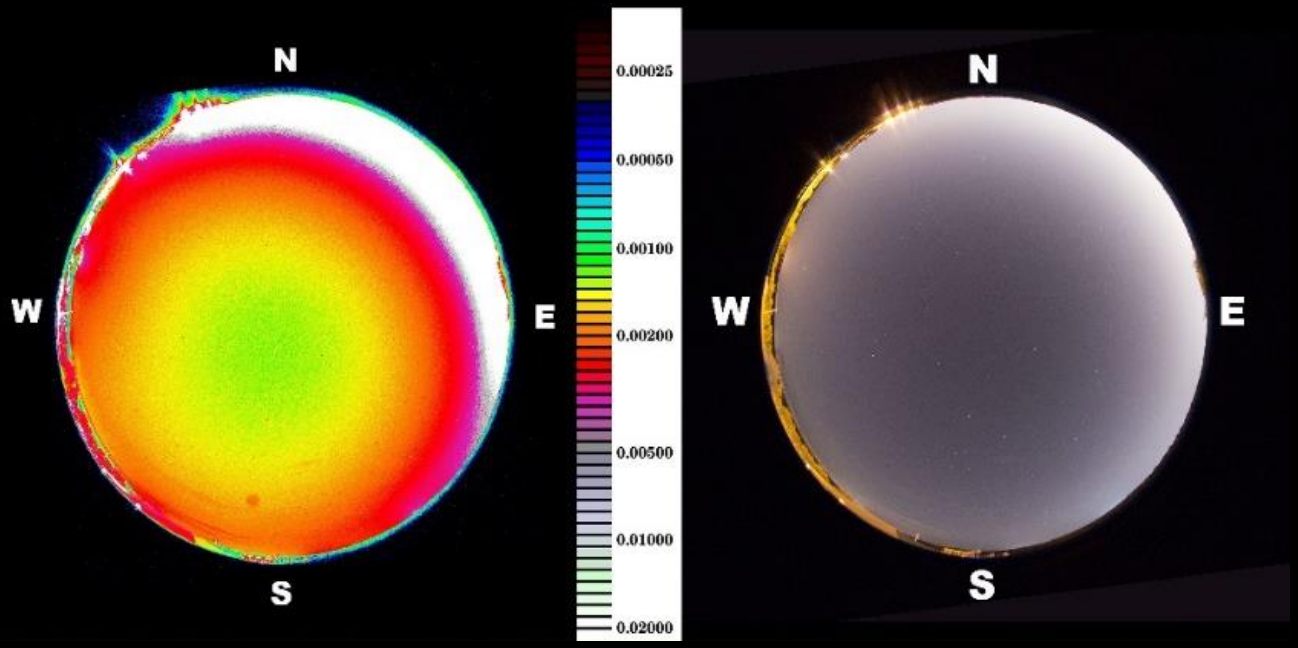
Let’s Dream!



Responsive Lighting

Assessing than Mitigating

Skyglow Measurements to Lighting Ordinances



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