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Biological Impacts of Night Lighting from
Brookside Golf Course Improvements Project

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The Rose Bowl Operating Company (RBOC) is proposing to make changes to the Brookside Golf Course, located in the Arroyo Seco just north of the Rose Bowl itself, consisting of the reorientation, expansion, and lighting of the driving range, and the addition and lighting of a miniature golf course. RBOC issued an Initial Study/Mitigated Declaration (MND) in January 2023, followed by revisions and responses to received comments in May 2023. We were engaged by Mitchell M. Tsai, Attorney at Law, to review these documents relative to the potential adverse impacts of light pollution from the proposal project because of our extensive and specific expertise on artificial light at night and its effects on wildlife and humans (see list of publications, Section 7). In this review, we present substantial evidence that the proposed project will have significant adverse impacts from light pollution and that the MND fails as an informational document by perpetuating the absurdity that "the Project would not result in a permanent glow in the Arroyo Seco" and that "the proposed lighting at the driving range would not substantially differ from the current (or historical) conditions on the Project Site" (MND Response to Comments, p. 2-7). As discussed in detail below, these patently false assertions fail to meet the standards necessary to inform the public or to support a final decision by the City of Pasadena.

1 No Matter How Well Shielded, Sports Lighting Causes Light Pollution

The proposed project will cause significant light pollution, notwithstanding the commitment to follow the generic code for the City of Pasadena (Zoning Code Section 17.40.080(a)). Some understanding of how light is measured, and what the Zoning Code measures, is required comprehend why the analysis in the MND is so inadequate.

The code requires that "no lighting on private property shall produce an illumination level greater than one foot-candle on any property within a residential zoning district except on the site

of the light source." The code also has an admonition to direct light "downward" and away from adjoining properties.

The way lighting engineers typically measure light for compliance with an ordinance like this is to calculate the illumination from the proposed light on a horizontal plane at ground level surrounding the lights. Because the ordinance does not specify where or how the illumination is to be measured, the engineer will assume that it means horizontal illumination at the ground, which will always be less than if one measured the illumination on a vertical plane at the height that a person or animal might encounter the light. The measurement is just the amount of light falling per unit area on the ground, as if the sensitive receptor were looking straight up, lying on the ground. This measurement typically does not include any analysis of the scattering and reflecting of light, but rather is just the sum of the direct light from each of the lamps. The Pasadena Zoning Code is insufficient to achieve the mitigating effects attributed to it in the MND for several reasons.

First, horizontal illuminance only deals with illuminance (light falling on a surface) at the location of a sensitive receptor, not the visual apparency (glare and glow) of the lighted area itself. This is the difference between luminance (the glare and glow), which is measured in units that reference the brightness of the surface of the lamp and other items from which light is reflecting, and illuminance, which is the amount of light falling on a surface. Illuminance can be quite low, while luminance of the light source is still high. Consider looking at a bright LED flashlight across the length of a football field. The glare will be blinding (high luminance) but you probably would not be able to read a newspaper from the light (low illuminance). The ordinance regulates whether you can read a paper by the light, not whether it appears as a glowing area, or if the individual lamps are bright point sources visible to the observer. This bears repeating; as it is written, the code can be met while still exposing people and wildlife to high levels of light and glare.

Second, the threshold of 1 foot-candle is itself very high. For comparison the full moon in Los Angeles produces about 0.02 foot-candles of illumination and often is only 0.01 foot-candles. This means that the standard adopted for impacts in the MND allows light to be 50–100 times greater than the brightest natural conditions. Natural conditions, and the conditions through most of the month, are orders of magnitude lower still. This is a problem for the analysis in the MND because 1 foot-candle is bright enough to impact human and wildlife health through suppression of melatonin (Grubisic et al. 2019) and far exceeds all thresholds for impacting wildlife behavior (Prugh and Golden 2014, Schirmer et al. 2019, Simons et al. 2022, Longcore 2023).

Third, the measurement unit foot-candle is based on the sensitivity of human eyes to different colors of light and does not consider how bright the light appears to other species. The spectral composition of the lights will make them appear even brighter to some species, which will not show up in the analysis. For example, insects tend to be quite sensitive to light that is blue and violet and so lights that contain high levels of blue and violet will appear brighter to them than is captured by their measurement in foot-candles, which incorporates human sensitivity during the daytime and has low sensitivity to violet and shorter blue wavelengths.

Having reviewed the Zoning Code and the lighting plan for the proposed project (MND, Appendix A), anyone knowledgeable about light would understand that the claims in the MND

do not have a factual basis. In particular, the claims that the project would not cause permanent glow in the Arroyo Seco and that the project would not change the condition from current conditions are unsupported, and we turn to this issue next.

The proposed lighting system for the driving range includes 33 LED lights with a correlated color temperature (CCT) of 5700 K and an output of 85,000 lumens each. This information is not stated in the MND but is found in Appendix A, where the model of the lamps (CLIR 630 EV) is listed. Then, by consulting the specifications sheet from Phoenix Lighting for that model of light,[1] one learns the lumen output and CCT of the lamps. By multiplying 85,000 lumens by 33 it is seen that the total amount of light from the driving range alone (leaving aside any other lighting for pathways or the miniature golf course) will be 2.8 million lumens.

As a comparison with the light from the driving range, a 60-Watt incandescent bulb produces about 800 lumens, which means that the proposed lighting will be as bright as 3,506 60-Watt incandescent bulbs installed in the middle of the Arroyo Seco. Put another way, it would be as bright as 561 typical streetlights (at 5,000 lumens each) installed around the driving range. This amount of light will be noticeable and "glow" no matter how low the measured illumination is at the property boundary because all that light must go somewhere, and it will be reflected and scattered by aerosols and the air.

The angle at which light shines on a surface affects the amount of light that is reflected by that surface. When light shines straight down on turf, roughly 55% of the light is reflected upward. When the light is at a 60º angle, as little as 12% of the light is reflected upward. The average amount of light reflected upward from light shining on turf at angles of 60–90º is 20–25% (from figures produced by Dr. C. Baddiley, scientific advisor to the British Astronomical Association Campaign for Dark Skies). Taking this conservative estimate of 20–25% reflected light from turf (and it will be more in reality), the proposed driving range lights would result in 561,000–701,250 lumens of light emanating outward from the site (and unregulated by the code section relied upon as a mitigation). This would be the equivalent of 112–140 streetlights' worth of light directed upward into the sky and toward off-site receptors.

Light is also scattered by aerosols in the air. These can be dust, pollen, or droplets of water. The MND fails to account for the scattering of light from fog and clouds or other aerosols that will take place between the lamps and the ground, or the exacerbating effect of fog and clouds on the light that is reflected from the turf itself. Fog is extremely efficient at reflecting light and recent research has shown that foggy conditions result in a sixfold increase in night sky brightness (a measure of light pollution) (Ściężor et al. 2012). Furthermore, clouds reflect light downward, so even if it were only cloudy (and not also foggy), the light reflected downward would be substantially greater than that under a clear sky (Kyba et al. 2011, Ściężor et al. 2012). The MND does not account for either scattering of light by fog or reflection by clouds.

An assessment of light pollution from the proposed lighting should also consider scattering in the air, which is known as Rayleigh scattering. This type of scattering increases with shorter wavelengths of light, so the light from proposed full-spectrum lamps will be scattered. High

[1] https://www.phoenixlighting.com/sites/default/files/products/specification-sheets/n5400146f_clir_series_spec_sheet.pdf

CCT lamps, which are proposed for the project cause 10–20% more light pollution than high-pressure sodium lamps of the same luminous output (Bierman 2012). The proposed lighting will both exceed the illumination from streetlights in the Rose Bowl area, its CCT will result in even more light pollution. The preparers of the MND appear not to have any expertise in lighting or physics, because none of this is discussed and they made easily falsifiable claims that the driving range will not glow at night.

To the contrary, over half a million lumens of scattered light will create a glow that is always visible from off-site when the lights are illuminated, will contribute significantly to sky glow, and will adversely impact wildlife as discussed more in the following sections. Sports facilities are the second biggest contributor to light pollution in US cities, after commercial districts, and contribute far more to light pollution relative to their area than any other feature (Luginbuhl et al. 2009). This project is no different.

2 Biological Effects of Light Pollution

The analysis of impacts on biological resources, and aesthetic resources for that matter, depends on understanding and describing the difference between illuminance and luminance (also known as irradiance and radiance when measured in units not weighted to human vision). Although broadly related, it is possible for a project to cause significant new radiance sources in the nighttime visual environment (including through reflected light) even as irradiance around the property may or may not be elevated substantially.

To review, *illuminance* refers to the amount of light falling on a surface where something of interest is going on. It influences the visibility of items in the environment as well as the circadian (daily) rhythms of species. So, for example, small mammals respond to illumination in their foraging activities (Clarke 1983, Brillhart and Kaufman 1991, Vasquez 1994, Falkenberg and Clarke 1998, Kramer and Birney 2001, Prugh and Brashares 2010). It generally influences predator-prey relationships, including at levels of <0.01 foot-candle, far below the threshold of 1 foot-candle used in the MND (Kotler 1984, Simons et al. 2022).

Birds would be affected by increased ambient illumination at levels described in the MND. Species can forage at artificial lights (Goertz et al. 1980, Sick and Teixeira 1981, Frey 1993, Rohweder and Baverstock 1996) and experience significant changes in their morning singing times, especially since the lights will be turned on at 6 A.M. (Derrickson 1988, Miller 2006, Kempenaers et al. 2010, Longcore 2010). Those birds that sing earliest are responding to increases in illumination so faint that they are undetectable by humans (Thomas et al. 2002), and well below the resolution of the illumination diagram in the MND, which ignore reflected and scattered light. Such species would be affected at distances far beyond the 100-foot buffer used for biological resource analysis because of this sensitivity and the quantity of light that would reach beyond the lower resolution of precision for the lighting diagram.

Luminance refers to the brightness of the lights themselves, even as visible from a distance and even if they only negligibly increase *illuminance*. Merely seeing lights at a distance can influence the wayfinding and habitat use of an animal (Beier 1995). It is the overall luminance created by the project that will attract insects and migratory birds to their detriment, while

simultaneously reducing the value of the golf course and surroundings as a wildlife movement corridor by bats as well as terrestrial mammal species, contrary to the assertions in the MND.

2.1 Attraction of insects to light

Insects are attracted to light because they perceive the luminance of the light and adjust their behavior in response. Many families of insects are attracted to lights, including moths, lacewings, beetles, bugs, caddisflies, crane flies, midges, hoverflies, wasps, and bush crickets (Sustek 1999, Kolligs 2000, Eisenbeis 2006, Longcore et al. 2015, Owens et al. 2020, Deichmann et al. 2021). Insects attracted to lights are subject to increased predation from a variety of predators including bats, birds, skunks, toads, and spiders (Blake et al. 1994, Frank 2006). The lights proposed for use on the driving range would have a high CCT (5700 K) and therefore can be expected to be far more attractive to insects than lower CCT lights (Eisenbeis and Eick 2011, Hauptfleisch and Dalton 2015, Longcore et al. 2015, Donners et al. 2018, Longcore et al. 2018, Deichmann et al. 2021). Some studies have shown inconclusive results with respect to CCT (Pawson and Bader 2014, Haddock et al. 2019), but mechanistic assessments (Donners et al. 2018), studies in light-naïve environments with high insect diversity (Deichmann et al. 2021), and assessments of invertebrate visual systems (Longcore 2023) strongly suggest that the high CCT lamps proposed for the driving range lighting will exacerbate the attraction of insects.

2.2 Attraction of migratory birds

During a 2022 playoff game at Dodger Stadium between the San Diego Padres and the Los Angeles Dodgers, a Lesser White-fronted Goose entered the stadium and attempted a landing on the field. To light pollution experts, this was easily recognized as a case of a nocturnally migrating species being attracted to and disoriented by lights at night (Longcore 2022). The phenomenon of migratory birds being attracted to lights at night is well known and studied, in contexts ranging from communication towers to ceilometers to tall buildings and cruise ships (Gauthreaux and Belser 2006, Longcore et al. 2008, Bocetti 2011, Longcore et al. 2012, 2013, Van Doren et al. 2017, Horton et al. 2019, Van Doren et al. 2021, Burt et al. 2023). The MND does not consider the interference with movement of native migratory species represented by the introduction of a large, highly visible light source in an area traversed by millions of birds each year. Recently developed tools using weather radar estimate that 22 million birds traversed Los Angeles County during the spring 2023 migration, with close to 200,000 at peak times (see https://dashboard.birdcast.info/region/US-CA-037?night=2023-05-17).

Shielding the lights would not eliminate attraction of birds, because the proposed lights will be so bright, and the light will be reflected and scatter. Remote sensing studies already show that sports fields (even when lights are shielded) are the most significant contributors to light pollution in cities, and those same measures of light pollution (upward radiance) directly influence the distribution of migratory birds, as documented in many recent studies (La Sorte et al. 2017, Van Doren et al. 2017, McLaren et al. 2018, Burt et al. 2023). Light is reflected, scattered by fog, and reflected by low clouds. One of the higher bird mortality events at a wind turbine installation occurred at a location with lights that were at ground level and created a light attraction in conjunction with fog (Kerlinger et al. 2010, Kerlinger et al. 2011). Reflected light is more than adequate to attract migratory birds. Lebbin et al. (2007) documented an interspecific flock of migratory songbirds that gathered under stadium lighting consisting of 156 1500-Watt

metal halide lights illuminating a stadium at a university. Nothing about the design of the lights at Brookside Golf Course would make them proportionally any less attractive to migratory birds than other existing examples of birds being attracted to lights at sports fields.

Unless mitigated, the described lighting on its own would constitute a significant adverse impact on movement of native wildlife species through its impacts on migratory birds.

2.3 Disruption of movement of native terrestrial wildlife

The project site and immediate surroundings are well within the range of and can expected to be used by native mammals. Species observed on the property include coyotes and mule deer, while bobcat has been observed near the project site and mountain lion approximately 1 km away within the Arroyo Seco. Each of these can be easily verified with photographs on the iNaturalist website. The irradiance and radiance produced by the project would affect the distribution of these species. We know this from extensive camera trap studies of coyotes (Schirmer et al. 2019), habitat use studies of mule deer, mountain lion, and bobcat (Rockhill et al. 2013, Ditmer et al. 2020), and radiotelemetry of mountain lions (Beier 1995). We can add to the published research a study currently in review for publication and already presented at a scientific conference that evaluated mountain lion habitat preference in Orange and San Diego counties using GPS data from 102 individuals (Barrientos et al. 2023). After accounting for other factors, the analysis found that light escaping upward from the landscape and visible by a satellite from overhead was highly negatively associated with habitat use by mountain lions at the scale of about 500 m. That is, the lighting of the driving range, which would dramatically increase the brightness of the area (through reflected light), would dramatically reduce the probability that its surrounding part of the Arroyo Seco would be used as a movement corridor by mountain lions. This, too, would represent a significant adverse impact on biological resources that is not disclosed in the MND.

The MND erroneously states the following, in the Biological Resources appendix: "Nighttime light spillage associated with the operation of the driving range and proposed miniature golf course is not expected to significantly disrupt wildlife movement when considering existing conditions" (Appendix C, p. 17). The preparers do not reference any of the peer-reviewed literature and base their conclusion on the proposed limits on horizontal illumination, when those levels of illumination are known to impact space use of relevant species (Schirmer et al. 2019). Furthermore, luminance (radiance) is equally important in determining habitat use for species moving across the landscape. The conclusion in the MND that the lighting would not affect wildlife movement therefore is not supported by substantial evidence.

2.4 Spectrum of lights proposed increases biological impacts

As already discussed, the environmental analysis for the project does not incorporate any of the voluminous research that shows the differential effects of different wavelengths of light on biological systems (Longcore 2023). Neither the aesthetics analysis nor the biological resources analysis takes into account the wavelengths of light that would be produced by the proposed project.

The conclusion from a number of studies on humans and wildlife is that whiter light (that is, full-spectrum light with blue and violet light included) has more adverse impacts (Pauley 2004, Rich

and Longcore 2006, van Langevelde et al. 2011, Gaston et al. 2012, Stone et al. 2012, Longcore et al. 2015, Longcore 2018, Longcore et al. 2018, Gaston and Sánchez de Miguel 2022). The MND does not even discuss this important feature of the project design and one even has to track down the specification sheet for the lights to be used to ascertain that 5700 K LEDs will be used. Although the sheer quantity of light to be used makes it impossible to fully mitigate the impacts of the project, the inevitable adverse impacts could be reduced slightly by reducing the CCT of the lights to be used so that they will cause less scattering in the atmosphere (Kinzey et al. 2017), have a reduced effect on circadian rhythms, and reduce wildlife impacts for the groups of species that are highly sensitive to blue light.

3 Mitigation Measures

The MND relies on two mitigation measures to argue that impacts from light at night will be reduced to a less than significant level. In the biological section, the following mitigation measure is proposed:

MM-MIO-2. *To minimize potential indirect impact to nesting birds that may utilize ornamental/landscape vegetation on site and/or wildlife movement along the Arroyo Seco, nighttime lighting associated with the driving range and miniature golf course shall be shielded downward to limit spillage onto these sensitive receptors.*

As discussed at length above, shielding lights is insufficient as a mitigation measure when so much light is going to be used that the reflected light itself will be the brightness of 112–140 streetlights. The reflection and scattering are unavoidable physical processes. Furthermore, the mitigation measure does not address impacts to migratory birds for the same reason.

In the aesthetics section of the MND a separate mitigation measure is proposed:

MM-AES-1. *Upon design of the Project, including both miniature golf and driving range lighting fixtures, RBOC shall prepare a quantified lighting study to confirm that final lighting configurations will not exceed 1.0 foot candle from the property line. Prior to installation of final lighting features, RBOC shall conduct a directional lighting test to further determine no exceedance of 1.0 foot candle of light spill.*

As already noted, this "mitigation measure" simply confirms that the project will conform with the existing Zoning Code for the City of Pasadena and offers no additional mitigation that is specific to biological setting or the sensitive resources that are acknowledged to be present. Mitigation measures must reduce impacts beyond the status quo and yet this measure applies the same lighting standard as would be acceptable in the most active commercial zone in the City to a location that is both historically significant and biologically sensitive. The threshold his comically high — 50–100 times brighter than the light of a full moon, allowing illumination that would meet street lighting standards to be experienced at the property boundary. It does not seem like anyone writing the MND understands that this limit would be far too bright to be effective at reducing the impacts from the light to a less than significant level.

4 Conclusion

Based on the analysis above, we conclude that *the project goal of a lighted driving range cannot be achieved without significant adverse impacts on biological resources*. The analysis in the MND is missing key information such as the cumulative light emissions and does not do the modeling necessary to fully visualize and quantify the impacts to the nighttime environment that result from the introduction of 2.8 million lumens of light. Impacts to migratory birds are not addressed at all, and conclusions of mitigated impacts on movement of terrestrial wildlife and nesting birds are not supported by any evidence. Comparison of the proposed project lighting with conditions known to affect wildlife behavior and physiology support our conclusion that the project will have a significant adverse impact. Make no mistake about it, the Arroyo Seco will glow while the proposed lights are on, and this impact will be amplified by the presence of low clouds and fog such that it is foreseeable that neighbors will be able to read a newspaper by the reflected and scattered light, just as one can next to the Rancho Park Golf Course driving range in Los Angeles.

5 About the Authors

Travis Longcore and Catherine Rich are principals of Land Protection Partners. Dr. Longcore is Adjunct Professor in the Institute of the Environment and Sustainability at UCLA. He has taught, among other courses, Bioresource Management, Environmental Impact Analysis, Field Ecology, and Ecological Factors in Design. He was graduated *summa cum laude* from the University of Delaware with an Honors B.A. in Geography, holds an M.A. and a Ph.D. in Geography from UCLA, and is professionally certified as a Senior Ecologist by the Ecological Society of America and as a GIS Professional by the Geographic Information System Certification Institute. He is a 24-year member of the Los Angeles County Environmental Review Board and recently received the Galileo Award for outstanding academic work on light pollution over a multi-year period. Catherine Rich is Executive Officer of The Urban Wildlands Group. She holds an A.B. with honors from the University of California, Berkeley, a J.D. from the UCLA School of Law, and an M.A. in Geography from UCLA. She is lead editor of *Ecological Consequences of Artificial Night Lighting* (Island Press, 2006) with Dr. Longcore. In 2001, she was presented with the International Dark-Sky Association Executive Director's Award for outstanding service in protecting the nighttime environment. Longcore and Rich have authored or co-authored over 65 scientific papers in top peer-reviewed journals such as *Auk, Biological Conservation*, *Conservation Biology*, *Environmental Management*, *Frontiers in Ecology and the Environment*, *Trends in Evolution and Ecology*, and *Urban Forestry and Urban Greening*. Longcore and Rich have provided scientific review of environmental compliance documents and analysis of complex environmental issues for local, regional, and national clients for 25 years.

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