Rosemont Copper Project: Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

Prepared for: Rosemont Copper Company

Prepared by: WestLand Resources, Inc.

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1. INTRODUCTION

WestLand Resources, Inc. (WestLand) was retained by Rosemont Copper Company (Rosemont) to prepare a series of technical memorandums to supplement the Biological Assessment for the Rosemont Copper Project (the Project). The Draft Environmental Impact Statement (DEIS) for the Project (USDS 2011) summarized the potential effects of light, based largely on the initial lighting plan for the Project (M3 2009), on biological resources, including endangered species and critical habitat. Since the publication of the DEIS, Rosemont has proposed to modify their lighting program to avoid and minimize the extent and effect of light on the night sky and more specifically on listed species and critical habitat. The specific conservation measures proposed as outlined by Monrad (2012) are:

1) Employ 21st century lighting sources that operate well under dimmed conditions and can be adaptively controlled to reduce the amount of light emitted,
2) Employ shielded lighting sources to reduce the amount of uplight emitted,
3) Use lighting sources or filters to eliminate certain wavelengths of light (less than 500 nm) that attract wildlife,
4) Use the smallest necessary light source for applications to reduce the amount of light emitted, and
5) Employ lighting on mobile equipment to reduce stray light.

This memorandum analyzes the potential effects of the proposed lighting conservation measures for the Project on the following endangered species and critical habitat: Chiricahua leopard frog (Lithobates chiricahuensis) and its critical habitat, lesser long-nosed bat (Leptonycteris yerbabuenae), jaguar (Panthera onca) and its proposed critical habitat, and ocelot (Leopardus pardalis). We begin with a brief discussion of the lighting plan to be implemented by Rosemont. We then perform an analysis of the geographic extent of the potential effects of lighting from the Project, provide an estimate of the degree of skyglow expected from the Project, and discuss how the proposed lighting conservation measures could affect endangered species and critical habitat.

2. LIGHTING PLAN FOR THE ROSEMONT COPPER PROJECT

Rosemont has developed a lighting plan to be implemented in order to minimize the amount of light illumination associated with the Project (Monrad 2012). The plan minimizes the geographic extent of light sources and reduces the light output of these sources. In addition, the lighting plan restricts the wavelengths of light emanating from lighting sources to longer wavelengths through lighting types and filters to be installed on lighting fixtures (Monrad 2012). As a result, the lighting plan for the Project is predicted to minimize the geographic extent of increased lighting and the potential impacts on endangered species.

The lighting plan discusses the total output of light from the Project in terms of lumens per acre (Monrad 2012), the metric used by Pima County’s lighting code to establish maximum light outputs for areas throughout Pima County (see http://cms3.tucsonaz.gov/sites/default/files/dsd/Codes-Ordinances/2012_outdoor_lighting_code_.pdf). The Project is predicted to emit lumens per acre that are less than 10
percent of the Pima County Code limit for residential zones (Zone E1a(5)) and less than 12 percent of the limit if mobile sources are included in the calculation (Monrad 2012). Moreover, these estimates of lumens per acre include lights associated with the leach pad that is no longer a part of the Barrel Alternative, and does not include “adaptive” lighting whereby motion sensing can reduce the amount of lighting by more than 50 percent (Monrad 2012). Thus, the calculations provided by Monrad (2012) likely over estimates the amount of lighting associated with the Project.

3. INCREASE IN LIGHTING ACROSS THE LANDSCAPE

While the data provided by Monrad (2012) is informative in defining the absolute amount of light associated with the Project after the implementation of the lighting conservation measures, it does not provide an explicit analysis of either the geographic distribution of lighting associated with the Project or the extent to which lighting from the Project will increase light levels in the surrounding areas that could be used by federally-listed species. To provide information on the degree to which lighting from the Project could influence areas outside of the general location of lighting sources, we performed two separate analyses.

First, to analyze the amount and attenuation of light from the Project horizontally, we simulated illumination from the Project based on the lumens from stable lighting sources associated with each section of the proposed mine as identified by Monrad (2012). A line-of-sight analysis was then performed to determine which portions of the landscape within a 12-mile radius1 of the Project would be in direct line-of-sight to the lights of the Project. The amount of light from the Project that would reach the areas with direct line-of-sight to light sources was then calculated. Note that this approach only estimates the amount of light that reaches the areas surrounding the Project by direct line-of-sight sources.

Next, the amount of skyglow that would be produced by the Project was estimated. The amount of skyglow was estimated using equations that allow for the determination of skyglow based on total lumens and the relationship between lumens from light sources and the population of cities. The sections below provide more detail of these methods.

3.1. SIMULATION OF HORIZONTAL LIGHT

The Rosemont feasibility study (M3 2012) depicts the three dimensional surface of the Project through time. This study was used to generate a three dimensional surface for the mine at three time snapshots through the Project’s life: Startup (year 0), middle (year 10), and completion (year 21.3). Figures from the feasibility study (Figures 16-1, -24, and -27 in M3 2012) were georeferenced and contour lines were traced into ArcGIS. The contour lines were then used as known points to interpolate a three dimensional surface. The interpolated surface was merged with the existing USGS National Elevation Dataset (NED) 10m digital elevation model for each of the three time periods to create a modified Digital Elevation Model (DEM) on which to run the visibility analysis.

1 A 12-mile radius was defined to ensure inclusion of potentially affected areas and coincides with the study area used to initially identify seeps and springs that could be potentially affect by the Project (USDA 2011).
Monrad (2012) describes broad classes of lighting and the total lumens for each general light source, but it does not provide detail regarding the geographic placement, height above ground, or brightness of individual lights. The classes of lighting used in Monrad (2012) include Road Conflict Points (218,800 total lumens), Ore Processing (2,210,640 lumens), Dry Stack Conveyor (1,684,960 lumens) and the Mine Pit (90,086 lumens)². Using Monrad (2012) and M3 (2012) as guides, WestLand digitized the locations of representative lights within each lighting zone. For example, M3 (2012) depicts the maximum extent of the Mine Pit area, which will be lit by a maximum of 90,086 lumens (exclusive of vehicle mounted lights which are not considered in our model). WestLand approximated individual lights within the pit by placing points across the maximum pit extents on a 200m grid, resulting in 67 light points representing 1,344.6 lumens each. Monrad (2012) does not provide details on the height of these light sources therefore, we assumed that light sources in the pit area will be 30 feet (9.144m) above ground. A similar method was used for the Ore Processing area using a 100m spacing, resulting in 91 light points representing 24,292.8 lumens each, assuming that lights sources would be 40 feet (12.192m) above ground. The Traffic Conflict Points lighting zone was modeled as a set of 10 points at intersections depicted in M3 (2012). Each of these locations was assigned 21,880 lumens, at 30 feet (9.144m) above the ground. The Dry Stack Conveyor was simulated as a 2.5km line extending from the center of the Ore Processing zone to the approximate center point of the tailings impoundment. Light points were placed every 50m along this line, resulting in 53 light points representing 31,791.7 lumens each, at 40 feet (12.192m) above the ground surface. Using this method, the points representing individual lights do not move horizontally through time. That is, lights are assumed to be in the same location over the 21.3 year span of the mine operation. The lights, however, do move vertically through time as ground surface contours change. As the surface of the Pit descends below the original ground surface, the light points follow this surface down, remaining 30 feet (9.144m) above the modeled ground surface for each time period. The same holds true for the simulated Dry Stack Conveyor light points, which remain 40 feet (12.192m) above the modeled ground surface which rises through time.

WestLand then performed a line-of-sight analysis to determine the number of lights of each class visible at any location within a 12-mile radius of the disturbance area associated with the Project, for each of the four lighting classes and each of the three time periods. This resulted in 12 raster datasets with values ranging from 0 to the maximum number of lights in each lighting class. For example, the Mine Pit raster for Year 10 has values ranging from 0 to 67. These values denote the number of Mine Pit light points visible from a given cell (10.3 m²) in the 12-mile radius study area. For example, cells with a value of zero indicate that no light from the mine pit should be directly visible at the location. Cells with a value of seven have seven lights visible at their location.

For each lighting class, the lumen values were then converted to lux (lumens/m²) for the entire 12-mile radius study area. Lux at a particular location was calculated by dividing a single light's lumen value by $\frac{2\pi r^2}{\pi}$, where $r$ is the distance between the observation location and the nearest light of the light class³. The single light lux value at each location was then multiplied by the number of lights visible at that location.

² Because of changes in the Barrel Alternative, we did not include lighting associated with the leach pad.
³ This formula provides an approximate decay function based on the geometry of the light being emitted from the light source.
location for each lighting class. The resulting product for each lighting class was summed to produce the lux at each location. This process was performed for each of the three time periods, using the modified digital elevation model to represent changes in the elevation of the lights through time. The resulting three raster datasets represent lux-maps that depict the geographic extent and amount of light resulting from Project lighting.

3.2. ESTIMATION OF SKYGLOW

We based our analysis of skyglow on the model developed by Garstang (1986) and updated by Davis et al. (2006). Davis et al. (2006) determined that for Pima County, the increase in lighting in a city is approximately 1,800 lumens per capita, assuming that all other variables (e.g. uplight fraction) are held constant. Using the projected 5.2 million lumens anticipated from the Project, including both stable and mobile light sources (Monrad 2012), the resulting skyglow from the Project lighting would be the equivalent of a city with a population of approximately 2,900 people. Using stable lighting only, the resulting skyglow from the Project would be equivalent to a city with a population of approximately 2,300 people. Sells, Arizona, has a population of about 2,500 (2010.census.gov), and is the closest city that would be comparable to lighting from the Project. The footprint of skyglow for Sells, Arizona, as estimated from imagery provided by International Dark-Sky Association (http://www.blucemarble.de/nightlights/2010), is comparable to the area of perimeter fence of the Project. Because Pima County has established stringent regulations concerning outdoor lighting, a city in Pima County that is subject to lighting restrictions may offer a more reasonable comparison to skyglow expected from the Project. Ajo, Arizona, is subject to Pima County lighting codes, and has a current population of approximately 3,300 people (2010.census.gov). Skyglow from the Project is expected to be comparable, but less than, skyglow from Ajo, Arizona. Table 1 provides broader context to compare the anticipated skyglow of the Project to lighting from nearby cities.

Table 1. Population and lumens associated with communities near the Project. Population sizes and lumens provided by USDA (2011).

<table>
<thead>
<tr>
<th>Communities</th>
<th>Population</th>
<th>Lumens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tucson/Eastern Pima County</td>
<td>1,050,000</td>
<td>1,795,500,000</td>
</tr>
<tr>
<td>Nogales, Sonora, Mexico</td>
<td>160,000</td>
<td>273,600,000</td>
</tr>
<tr>
<td>Sierra Vista</td>
<td>43,320</td>
<td>74,077,200</td>
</tr>
<tr>
<td>Benson</td>
<td>4,833</td>
<td>8,264,430</td>
</tr>
<tr>
<td>Proposed Rosemont Mine (w/ mobile equipment)</td>
<td></td>
<td>5,188,831</td>
</tr>
<tr>
<td>Proposed Rosemont Mine (w/out mobile equipment)</td>
<td></td>
<td>4,204,486</td>
</tr>
<tr>
<td>Tubac</td>
<td>2,000</td>
<td>3,420,000</td>
</tr>
<tr>
<td>Sonoita</td>
<td>910</td>
<td>1,556,100</td>
</tr>
</tbody>
</table>

4. POTENTIAL EFFECTS ON ENDANGERED SPECIES

The results of this simulation indicate that the areas surrounding the Project will be largely unaffected by light from lighting sources associated with the Project. This is particularly true for areas outside of the perimeter fenceline, as the majority of the area predicted to be substantially impacted by increased
lighting from the Project exists within the fenceline (Figures 1-3). The amount of additional light above ambient conditions that many of the areas outside of the perimeter fenceline could experience is also relatively small, representing an increase in lux equivalent to between a moonless, starlit night\(^4\) and a quarter moon (Figures 1-3). However, because the Project will increase light levels over ambient conditions, and even small increases in nighttime lighting can have effects on wildlife (e.g. Buchanan 2005), we discuss below the potential effects of the increase in light, as estimated by our direct line-of-sight simulation, on several endangered species that could occur in the vicinity of the Project: Lesser long-nosed bat, jaguar, ocelot and Chiricahua leopard frog. We also discuss the potential impacts on these species of an increase in skyglow as a result of lighting from the Project.

### 4.1. Potential Effects on Lesser Long-nosed Bat

The data provided by Monrad (2012) is informative regarding the absolute amount of light associated with the Project, and can be used to examine the potential effects of nighttime lighting from the Project on wildlife species of interest. The lumens per acre predicted for the lighting associated with the Project is substantially lower than areas in Pima County zoned for low light levels (Zone E1a(5)). In a study of foraging and movement of lesser long-nosed bats in the Tucson Basin, Lowery et al. (2009) concluded that bats avoided areas zoned for high lighting, but preferentially used areas zoned for low lighting (less than 12,000 lumens per acre), although this effect was correlated with distance to washes. Because the lighting associated with the Project will be considerably less (1,100-1,400 lumens per acre) than the limit associated with the areas in Pima County zoned for low lighting, effects on foraging lesser long-nosed bats for Project lighting could be minimal.

The area surrounding the Project that will be directly impacted by increased light from the Project will also be limited, and the amount of light that reaches these areas will be slight. The increase in lumens per acre, even at some of the areas with the highest increase in light (e.g. 1 lumen/m\(^2\) or approximately 4,050 lumens per acre), will be far less than the maximum lighting allowable in areas of the Tucson Basin that are selectively used by foraging bats (12,000 lumens/acre; Lowry et al. 2009). Numerous reports of lesser long-nosed bats using hummingbird feeders in and around Tucson, Arizona (Arizona Bat Research Group 2003), also suggest that this species is not negatively affected by relatively low levels of horizontal lighting or skyglow. While increased nighttime lighting from moonlight can influence nighttime activity in bats (Saldaña-Vázquez and Munguia-Rosas 2012), data from lesser long-nosed roosts in Arizona do not show a pattern between roost emergence and moonlight (WestLand, unpublished data). Thus, the effects on lesser long-nosed bats as a result of increased lighting from the Project are expected to be limited.

\(^4\) Because measurements of lux values for moonlight conditions are quite variable, in order to inform the interpretation of lux values across the landscape, we used a lux scale described by Rich and Longcore (2006) that summarizes measurements from a variety of sources. Studies of the effects of lunar illumination on reptiles that inhabit desert and open-habitat regions report lux values associated with lunar illumination that are much higher (e.g. Clarke et al. 1996, Weaver 2011). Thus, our use of Rich and Longcore (2006) to interpret lux values is conservative.
4.2. **POTENTIAL EFFECTS ON JAGUAR AND PROPOSED JAGUAR CRITICAL HABITAT**

Increased nighttime lighting could affect jaguars as a species and proposed jaguar critical habitat. Potential effects to each are discussed in the sections below.

4.2.1 **Effects to Jaguars as a Species**

Jaguars are largely nocturnal predators in the dry forests of the northern portion of their range (see references within Harmsen et al. 2010). Thus, nighttime lighting could influence their movement and foraging behavior.

As stated above, according to a line-of-sight analysis, the area surrounding the Project that will be directly impacted by increased light from the Project will be limited, and the amount of light that reaches these areas will be slight. Studies of foraging jaguars indicate that their overall activity is not influenced by natural variation in nighttime lighting caused by brighter illumination associated with lunar phases (Harmsen et al. 2010). However, the use of habitats by jaguars for foraging is influenced by the activity patterns of prey species. For example, prey species that reduce activity during full moon lunar phases appear to influence jaguar activity patterns such that jaguars may forage in other areas where different prey species are more active (Harmsen et al. 2010).

Thus, it is unlikely that slight increases in horizontal light levels that will be mostly smaller than natural variations in lunar illumination (e.g., approximately 0.001-0.03 lux; Rich and Longcore 2006), over a small area outside of the Project perimeter fenceline, will directly affect jaguar foraging or movement. However, indirect effects on foraging patterns due to changes in the behavior of prey species could occur. While lighting from the Project will increase skyglow in the vicinity of the Project, it will be relatively small and geographically limited. Thus, potential impacts on the foraging behavior of jaguars should also be limited.

4.2.2 **Effects to Proposed Jaguar Critical Habitat**

One of the Primary Constituent Elements (PCEs) of proposed critical habitat is low human influence (USFWS 2012). The GIS database apparently used by USFWS (2012) to map this PCE evaluated the level of stable nighttime lighting in its calculation of human influence (SEDAC 2012). Thus, increased lighting due to the Project could affect proposed jaguar critical habitat.

As described in a previous memorandum (WestLand 2012), it appears that the entire proposed critical habitat in the vicinity of the Project is already above the threshold of human influence established by the proposed rule to designate critical habitat for the jaguar (USFWS 2012). Thus, increased lighting from the Project by definition cannot increase human influence such that the PCE of low human influence no longer exists in the vicinity of the Project. Furthermore, according to a line-of-sight analysis, the proposed critical habitat surrounding the Project that will be directly impacted by increased light from the Project, will be limited, and the amount of light that reaches these areas will be slight (**Figures 4-6**). The increase in skyglow as a result of the Project will also be relatively limited. We do not know exactly how stable
nighttime lighting was calculated in the GIS database used by USFWS to map the PCE of low human influence, thus the increased lighting from the Project may or may not substantially increase the human influence metric used to identify PCEs for proposed jaguar critical habitat.

4.3. POTENTIAL EFFECTS ON OCELOT

Similar to the jaguar, ocelots are largely more active at night than during daylight hours (Di Bitetti et al. 2006, Harmsen et al. 2010). Thus, their movement and foraging behavior could be influenced by increased lighting from the Project.

As stated above, according to a line-of-sight analysis, the area surrounding the Project that will be directly impacted by increased light from the Project will be limited, and the amount of light that reaches these areas will be slight. Studies of ocelots indicate that their overall activity is not influenced by natural variation in nighttime lighting caused by brighter illumination associated with lunar phases (Harmsen et al. 2010). However, some findings suggest that ocelots use denser habitats in response to increased nighttime lighting (see references in Harmsen et al. 2010). Ocelots could also be indirectly influenced by increased lighting due to changes in activity patterns of their prey (Grigione and Mrykalo 2004), although direct evidence of this possibility is lacking.

Thus, slight increases in horizontal light levels over a small area outside of the Project perimeter fenceline and increased skyglow could affect ocelot foraging and movement by shifting activity towards denser habitats. However, the consequences of a shift in habitat use are unclear.

4.4. POTENTIAL EFFECTS ON CHIRICAHUA LEOPARD FROG

Increased nighttime lighting could affect the Chiricahua leopard frog as a species and Chiricahua leopard frog critical habitat. Potential effects to each are discussed in the sections below.

4.4.1 Effects to the Chiricahua Leopard Frog as a Species

There is evidence of negative effects of increased nighttime lighting in a variety of frog species (e.g. Buchanan 2005). Thus, increased lighting from the Project could affect Chiricahua leopard frogs in the vicinity of the Project.

According to a line-of-sight analysis, the area surrounding the Project that will be directly impacted by increased light from the Project will be limited, and the amount of light that reaches these areas will be slight. Some sites where Chiricahua leopard frogs have been detected are predicted to be subject to increased light levels, although this increase would be slight (Figures 7-9). Small increases in light can have effects on anurans (see Buchanan 2005), although many experimental studies of the effects of light on frogs use treatment levels (e.g. 3.8-12 lux; Buchanan 1993) far above the predicted increase in light from the Project. Moreover, all of the known frog breeding sites in the Greaterville area, as well as the areas surrounding Empire Gulch and Upper Cienega Creek, are not predicted to experience increased light using our line-of-sight analysis (see Figures 7-9). Skyglow as a result of lighting from the Project is
also expected to be relatively limited in geographic extent (see Sec. 2.2.). Thus, lighting from the Projects is unlikely to affect substantially any leopard frogs that might occur in the vicinity of the Project.

An additional aspect of Rosemont’s lighting plan will minimize effects to leopard frogs that might occur in the vicinity of the Project. The lighting described in Monrad (2012) will consists of amber light – emitting diodes (LEDs) and lights equipped with a filter to exclude short wavelengths of light. Many frog species exhibit a preference for short wavelengths, including many Lithobates [Rana] species (Hailman and Jaeger 1974), although this effect is not seen under all experimental circumstances (Kicliter and Goytia 1995). Thus, by excluding these wavelengths, Rosemont’s lighting plan will minimize the influence of lighting from the Project on the movement, including dispersal patterns, of Chiricahua leopard frogs.

4.4.2 Effects to Chiricahua Leopard Frog Critical Habitat

Chiricahua leopard frog critical habitat is not predicted to experience increased horizontal light levels from the Project (Figures 7-9), and skyglow as a result of Project lighting is anticipated to be relatively limited in extent (see Sec 2.2.). The exclusion of short wavelengths of light is expected to minimize the effect on movement of frogs into and among portions of critical habitat. Thus, we expect no impacts to Chiricahua leopard frog critical habitat using the approach taken by our analysis.

5. CONCLUSION

Rosemont has proposed specific lighting conservation measure to avoid and minimize the impact of light on listed species and critical habitat. In order to inform the potential effects of these lighting conservation measures associated with the Project on endangered species and critical habitat, WestLand designed a spatial model that simulated the geographic locations of light sources associated with the Project and the amount of light to be emitted by these sources. Using a line-of-sight analysis coupled with a decay function to account for the decrease in the amount of light as distance from a light source increases, this model informs both the geographic extent of light and the amount of light that could result from the Project. We modeled three stages of mine development to account for changes in topography due to tailings impoundment and waste rock storage. WestLand also calculated the expected degree of skyglow as a result of Project lighting to be relatively limited in geographic extent, and similar to the city of Sells, Arizona. The results of these models and calculations indicate that the area surrounding the Project that will be directly impacted by increased light from the Project will be limited, and the amount of light that reaches these areas will be slight. This slight increase and limited geographic extent of additional light from the Project could influence foraging behavior of any jaguars and ocelots that might occur in the vicinity of the Project. However, these increased light levels are not expected to preclude these areas from use by jaguars and ocelots. The increase in stable nighttime lighting associated with the Project could increase the level of human influence in the areas of proposed jaguar critical habitat surrounding the Project. However, it appears that human influence is already higher than the threshold established by the proposed rule to designate jaguar critical habitat. It is also unclear whether or not the slight increase in light levels over a limited geographic area will increase human influence to such an extent as to
negatively affect proposed critical habitat. Light levels are not predicted to increase in most of the areas where Chiricahua leopard frogs have been documented since 2008, and no breeding locations or areas of Chiricahua critical habitat are predicted to experience increases in light from the Project. In addition, Rosemont’s lighting conservation measures will exclude short wavelengths of light that attract many frog species, and thus minimize potential effects of these light sources of leopard frog movement.
6. LITERATURE CITED


Pima County, Arizona,
Data Sources: ArcGIS Online,
Lux (lumen/[m²]) categories following Rich and
Longcore (2006)

Simulated Light Levels (Year 0)

Figure 1
Potential Effects of Lighting Associated with
the Rosemont Project on Endangered Species

ROSEMONT COPPER COMPANY

User: chuckp
Legend
Perimeter Fence
Analysis Area
Helena Mine
Legend
General Location of Light Sources
¢+ <0.001 lux - Darker than Clear Starry Night (No Color)
0.001 lux - Clear Starry Night
0.002 - 0.009 lux - Clear Starry Night to Quarter Moon
0.010 - 0.030 lux - Quarter Moon
0.031 - 0.099 lux - Quarter Moon to Full Moon
0.100 - 0.300 lux - Full Moon
> 0.3 lux - Brighter than Full Moon

N
0 2 4 Miles
Figure 2
Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

ROSEMONT COPPER COMPANY
SIMULATED LIGHT LEVELS (YEAR 10)

Legend

- General Location of Light Sources
- Perimeter Fence
- Analysis Area (12-Mile Radius from Disturbance Area)
- Helena Mine

Legend:
- <0.001 lux - Darker than Clear Starry Night (No Color)
- 0.001 lux - Clear Starry Night
- 0.002 - 0.009 lux - Clear Starry Night to Quarter Moon
- 0.010 - 0.030 lux - Quarter Moon
- 0.031 - 0.099 lux - Quarter Moon to Full Moon
- 0.100 - 0.300 lux - Full Moon
- > 0.3 lux - Brighter than Full Moon

Path: M:\Projects\1049.21\LIGHT\light_gis\mxd\revised_light_classes_20121120\figure02_yr10pt00.mxd
Date: 11/28/2012

User: chuckp

Pima County, Arizona,
Data Sources: ArcGIS Online,
Lux (lumen/m²/m²) categories following Rich and Longcore (2006)
Figure 3
Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

Legend
- General Location of Light Sources
- Perimeter Fence
- Analysis Area (12-Mile Radius from Disturbance Area)
- Helena Mine
- <0.001 lux - Darker than Clear Starry Night (No Color)
- 0.001 lux - Clear Starry Night
- 0.002 - 0.009 lux - Clear Starry Night to Quarter Moon
- 0.010 - 0.030 lux - Quarter Moon
- 0.031 - 0.099 lux - Quarter Moon to Full Moon
- 0.100 - 0.300 lux - Full Moon
- > 0.3 lux - Brighter than Full Moon
Pima County, Arizona, Data Sources: ArcGIS Online, Lux (lumen/m²) categories following Rich and Longcore (2006) ±

ROSEMONT COPPER COMPANY
Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species
SIMULATED LIGHT LEVELS (YEAR 0) AND PROPOSED JAGUAR CRITICAL HABITAT AND MOVEMENT CORRIDOR
Figure 4

Legend

- General Location of Light Sources
- Perimeter Fence
- Analysis Area (12-Mile Radius from Disturbance Area)
- Proposed Jaguar Critical Habitat
- 1% Modeled Jaguar Movement Corridor Between Proposed Critical Habitat Units (See Westland 2012)

| Lux Level | Description
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.001 lux</td>
<td>Darker than Clear Starry Night (No Color)</td>
</tr>
<tr>
<td>0.001 lux</td>
<td>Clear Starry Night</td>
</tr>
<tr>
<td>0.002 - 0.009 lux</td>
<td>Clear Starry Night to Quarter Moon</td>
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<tr>
<td>0.010 - 0.030 lux</td>
<td>Quarter Moon</td>
</tr>
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<td>0.031 - 0.099 lux</td>
<td>Quarter Moon to Full Moon</td>
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<td>0.100 - 0.300 lux</td>
<td>Full Moon</td>
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<tr>
<td>&gt; 0.3 lux</td>
<td>Brighter than Full Moon</td>
</tr>
</tbody>
</table>
Pima County, Arizona, Data Sources: ArcGIS Online, Lux (lumen/[m²]) categories following Rich and Longcore (2006)

Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

ROSEMONT COPPER COMPANY
Simulated Light Levels (Year 10) and Proposed Jaguar Critical Habitat and Movement Corridor

Figure 5
Pima County, Arizona,

Data Sources: ArcGIS Online,
Lux (lumen/m²/m²) categories following Rich and Longcore (2006)

ROSEMONT COPPER COMPANY

SIMULATED LIGHT LEVELS (YEAR 21.3) AND PROPOSED JAGUAR CRITICAL HABITAT AND MOVEMENT CORRIDOR

Figure 6

Legend

General Location of Light Sources
Perimeter Fence
Analysis Area
(12-Mile Radius from Disturbance Area)
Proposed Jaguar Critical Habitat
1% Modeled Jaguar Movement Corridor Between Proposed Critical Habitat Units (See WestLand 2012)

- <0.001 lux - Darker than Clear Starry Night (No Color)
- 0.001 lux - Clear Starry Night
- 0.002 - 0.009 lux - Clear Starry Night to Quarter Moon
- 0.010 - 0.030 lux - Quarter Moon
- 0.031 - 0.099 lux - Quarter Moon to Full Moon
- 0.100 - 0.300 lux - Full Moon
- > 0.3 lux - Brighter than Full Moon
Figure 7

Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

Chiricahua Leopard Frog Sites Identified by AGFD (2012) and Surveys Conducted by WestLand (2008-2012).

Legend
- General Location of Light Sources
- Perimeter Fence
- Analysis Area (12-Mile Radius from Disturbance Area)
- Chiricahua Leopard Frog Critical Habitat

Chiricahua Leopard Frog Sites
- Occupied
- Occupied with Signs of Breeding

Nighttime Simulated Light Levels (Year 0) and Chiricahua Leopard Frog Sites and Critical Habitat

Legend:
- <0.001 lux - Darker than Clear Starry Night (No Color)
- 0.001 lux - Clear Starry Night
- 0.002 - 0.009 lux - Clear Starry Night to Quarter Moon
- 0.010 - 0.030 lux - Quarter Moon
- 0.031 - 0.099 lux - Quarter Moon to Full Moon
- 0.100 - 0.300 lux - Full Moon
- > 0.3 lux - Brighter than Full Moon

Pima County, Arizona, Data Sources: ArcGIS Online, Lux (lumen/m²) categories following Rich and Longcore (2006).

ROSEMONT COPPER COMPANY

SIMULATED LIGHT LEVELS (YEAR 0) AND CHIRICAHUA LEOPARD FROG SITES AND CRITICAL HABITAT
Figure 7
Pima County, Arizona, Data Sources: ArcGIS Online, Lux (lumen/m²) categories following Rich and Longcore (2006)

Chiricahua Leopard Frog Sites Identified by AGFD (2012) and Surveys Conducted by WestLand (2008-2012).

Legend
- General Location of Light Sources
- Perimeter Fence
- Analysis Area (12-Mile Radius from Disturbance Area)
- Chiricahua Leopard Frog Critical Habitat

Chiricahua Leopard Frog Sites
- Occupied
- Occupied with Signs of Breeding

Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

ROSEMONT COPPER COMPANY
SIMULATED LIGHT LEVELS (YEAR 10)
AND CHIRICAHUA LEOPARD FROG SITES
AND CRITICAL HABITAT
Figure 8
Chiricahua Leopard Frog Sites Identified by AGFD (2012) and Surveys Conducted by WestLand (2008-2012).

Legend
- **General Location of Light Sources**
- **Perimeter Fence**
- **Analysis Area (12-Mile Radius from Disturbance Area)**
- **Chiricahua Leopard Frog Critical Habitat**

Chiricahua Leopard Frog Sites
- Occupied
- Occupied with Signs of Breeding

Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species

SIMULATED LIGHT LEVELS (YEAR 21.3) AND CHIRICAHUA LEOPARD FROG SITES AND CRITICAL HABITAT

Figure 9
Memorandum

To: Jim Upchurch, USFS CNF
Cc: Chris Garrett, SWCA
From: Kathy Arnold
Doc #: 074/12 – 15.3.2
Subject: Transmittal of Technical Memoranda
Date: December 18, 2012

Rosemont Copper is having delivered by courier, the following in hard copy and cd format. Included are three (3) hard copies and two (2) cds for the Forest Service and two (2) hard copies with one (1) cd for SWCA.

- Rosemont Copper Project: Potential Effects of Lighting Associated with the Rosemont Project on Endangered Species, dated December 7, 2012 by WestLand Resources, Inc.

Please do not hesitate to contact me should you require anything further.