Dark Skies

Introduction

The Coronado National Forest, with its topographic and biological diversity and unique "sky islands" ecosystems, provides many opportunities for recreation. The major recreational activities include developed and backcountry camping, hiking, sightseeing, biking, and scenic driving; the "Recreation and Wilderness" section of this chapter provides detailed information on these activities on the Coronado National Forest. For many, an important component of the recreational experience is night sky viewing. The cloudless night skies, minimal atmospheric pollution, and low humidity of the southwestern United States provide ideal conditions for this activity, besides maintaining the natural light conditions and fluctuations that are important to native plants and animals. Night sky viewing is an important aspect of Southwestern tourism (Cinzano 2000). The area within and adjacent to the Santa Rita Mountains in Pima County is particularly well suited for night sky viewing, and these excellent viewing conditions have been recognized and exploited by astronomers for many years. The Kitt Peak National Observatory and the Smithsonian Institution's Fred Lawrence Whipple Observatory are world-class astronomy research facilities located on the Coronado National Forest that rely on the area's naturally dark, unpolluted night skies for optical and infrared astronomy research.

Changes from the Draft Environmental Impact Statement

The impact of the Rosemont Copper Project outdoor lighting described in the DEIS was based on the first Rosemont Copper Project lighting plan (M3 Engineering and Technology Corporation 2011), which projected a total of 21,815,355 lumens for the Rosemont Copper Project. In order to attempt to reduce impacts, a subsequent lighting plan was prepared by Monrad Engineering for the Rosemont Copper Project (Monrad et al. 2012a). The revised plan was conducted for the Barrel Alternative. This revised plan projects a total of 5,791,151 initial lumens, a substantial reduction from the 2011 plan. The reduction in lumens is a result of the plan's use of LED lights with spectral controls to minimize lighting in the blue part of the light spectrum and shielding/beam control on nonfixed lights to minimize direct uplight. The Coronado requested additional information to evaluate the uplight ratios provided in Monrad et al. (2012a). Rosemont Copper submitted additional documentation, namely the August 17, 2012 "Rosemont Mine – Mitigation Recommendation Report Addendum" (Monrad 2012), which increased the projected lumen total to 6,423,646 lumens. The Monrad et al. (2012a) plan with Revision 2 was evaluated to determine the impact on dark skies using the same methodology that was employed for the DEIS. The resulting report, "An Assessment of the Impact of Potential Mining Operations at the Rosemont Copper Mine on the Night Sky of Southern Arizona" (Dark Sky Partners LLC 2012), discloses the potential impacts that the revised lighting plan would have to dark skies for the Barrel, Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives and is summarized in the "Environmental Consequences" part of this resource section. The original lighting plan and the modeling results specific to the proposed action are retained for that alternative and summarized in the "Environmental Consequences" part of this resource section as well.

Issues, Cause and Effect Relationships of Concern

Issue 8: Impact on Dark Skies and Astronomy

This issue relates to the potential for the mine operation and facilities to reduce night sky visibility. Many area residents, recreationists, research and amateur astronomers, and stargazers value the current dark skies in the area. Increased light and air particulates from mine related facilities,

equipment, vehicles, and processes have the potential to diminish dark skies. The increased sky glow could reduce the visibility of celestial objects, particularly the faint ones, which are often the subject of scientific study. Key observation points and the Smithsonian Institution's Fred Lawrence Whipple Observatory could be adversely affected.

Issue 8 Factor for Alternative Comparison

1. Increase in sky brightness resulting from mine facility and vehicle lighting

Analysis Methodology, Assumptions, Uncertain and Unknown Information

Analysis Area

The analysis area for analyzing potential impacts to dark skies and astronomy resulting from the action alternatives consists of all areas in which night sky viewing would potentially be affected by the proposed project. This includes the Santa Rita Ecosystem Management Area, where native plants, animals, and visitors would likely be affected, and surrounding areas in the region, where the project night lighting would be visible and could have potential impacts. These areas include eastern Pima County, Santa Cruz County, and western Cochise County. Six observation points between 1 and 15 miles from the proposed mine site, including two observatories, were chosen for modeling the potential impacts within the analysis area (figure 79). The temporal bounds of analysis are the premining and active mining phases of the project, from the time mine lighting is installed until mine closure, when lighting would be removed.

The effects of project area night lighting with other past, present (ongoing), and reasonably foreseeable activities within the region constitute the cumulative impacts. There are potential impacts to dark skies for Coronado National Forest plants and animals, visitors, and residents in the lands adjacent to and/or surrounding the project area; in addition, astronomy research observatories that are located in the analysis area could be impacted. Note that for cumulative effects, past and present actions are described and considered in the "Affected Environment" part of this resource section; reasonably foreseeable future actions that could cumulatively contribute to dark skies impacts are described and considered in the "Cumulative Effects" part of this resource section.

Methodology

Lighting related impacts to existing night sky conditions can be created by the upward spill of light from an unshielded light source. Dust, water vapor, and other particles suspended in the atmosphere will scatter and reflect light that is emitted into the atmosphere, creating a phenomenon called light pollution or "artificial sky glow." Light that escapes directly upward into the night sky is a major contributor to the loss of the dark night sky. Thus, unshielded or improperly controlled outdoor lighting can impede the view and adversely affect the view of a natural, dark, night sky (National Park Service 2007).

The method used to quantify the potential impacts of project area lighting on the region's existing dark sky conditions is based on a computer model that calculates sky glow or sky brightness caused by artificial outdoor lighting. The model accounts for the effects of light dispersion or reflection caused by grounded objects such as buildings, terrain, and vegetation; the model also accounts for light emitted by nearby cities and towns, housing developments, industrial areas, and shopping centers, with the capability of accounting for spatial distribution, shielding, and intensities of light

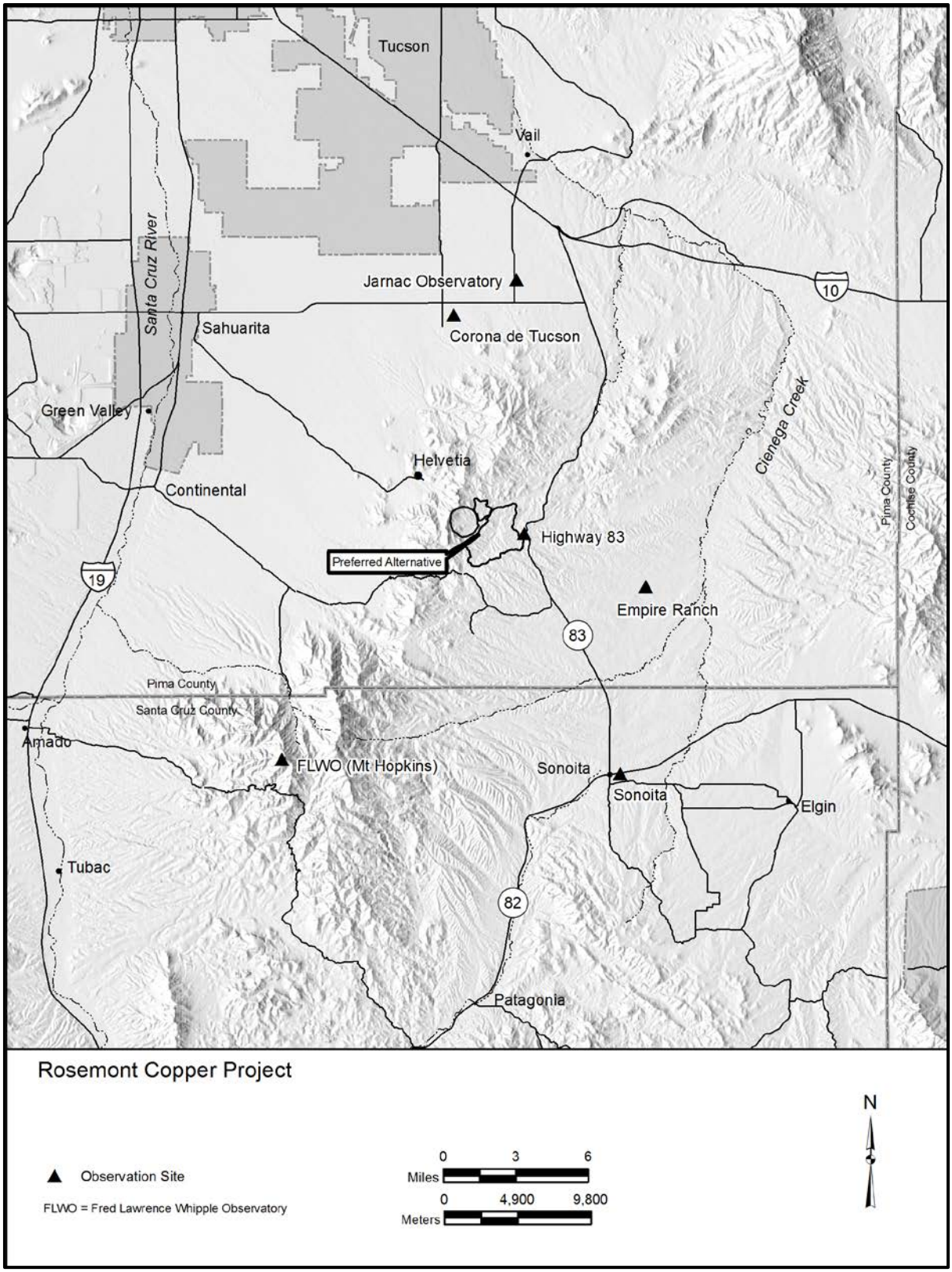

Figure 79. Analysis area for dark skies

sources. The physical model, along with all input parameters for the computer code, are given in "An Assessment of the Impact of Potential Mining Operations at the Rosemont Copper Mine on the Night Sky of Southern Arizona" and references therein (Dark Sky Partners LLC 2012).

The original and revised lighting plans specify that nighttime lighting would consist of four lighting uses: (1) fixed lights at the mine headquarters and ore processing area for parking and walkway illumination and security; (2) mobile lighting of mine pit shovels and ore loaders, along with portable light towers at the active mine site; (3) fixed roadway lighting at conflict points along the primary access road (from SR 83 to the mine site) and along in-mine roadways; and (4) fixed lighting at the dry-stack conveyor (Monrad et al. 2012a). Mine vehicle lighting (i.e., headlights) was not included in the revised lighting plan but was included in this analysis at the same level that was used in the 2010 analysis and in the DEIS. The direct uplight fraction was taken from the "Rosemont Copper Project Light Pollution Mitigation Recommendation Report" (Monrad et al. 2012a). Mine vehicular lighting was calculated under the assumption that a fraction (11 percent) of headlight light would be projected upward and that all vehicular lighting would be produced onsite (not on public roadways). The total intensity of light produced at all of these mine locations was calculated for all of the mine site light sources.

The computer code was augmented to include: (1) terrain blocking at the mine site; and (2) detailed spectral analysis of the proposed lighting. Spectra for the two lamp types proposed by Monrad et al. (2012b), the filtered LED (FLED) and amber LED (ALED) lights, were provided by Monrad Engineering. The computer code was modified to calculate the sky glow for each of the spectral bins for each lamp and then sum the contribution of each bin to find the total sky glow at each point in the analysis.

The model assumed that the largest source of nighttime lighting from cities and towns and remote residences relevant to the project area would be in eastern Pima County. Year 2010 U.S. Census (Census) data were used to calculate the approximate amount of light produced per capita, as well as the amount of outdoor light for communities without any outdoor lighting controls (Dark Sky Partners LLC 2011). For the project area, the total light intensity in areas around the mine site (in eastern Pima County) was calculated using the per capita light use of the populations of Tucson, Nogales, Benson, Sonoita, Tubac, and Sierra Vista.

Once lighting data had been collected for the proposed mine site and surrounding municipal light sources, site-specific analysis points were selected. The sites were chosen to represent the impacts to nearby astronomy observatories, to towns near the proposed mine, and to motorists traveling along SR 83 (where the maximum night lighting visual impact would most likely be because of proximity to the mine site). The night sky analysis points are as follows:

- Mount Hopkins (Whipple Observatory);
- Jarnac Observatory;
- The town of Sonoita;
- The town of Corona de Tucson;
- SR 83, at a point close to the mine; and
- Empire Ranch.

Using the above six observations points to assess the amount of sky glow or sky brightness that would be observed within the region, the computer model was run to predict the fractional increase in

sky brightness beyond current conditions that would be produced by the project's night lighting. Sky brightness was calculated from the sky zenith (directly overhead, at 0 degrees) to the horizon (90 degrees), with results showing the potential fractional increase in night sky brightness caused by the Rosemont Copper Mine.

Impacts to the astronomy industry based on the impacts that the revised lighting plan would have on dark skies are discussed in the "Socioeconomics and Environmental Justice" resource section.

Please note that the connected actions listed in chapter 2 were considered for their potential to contribute to impacts to dark skies. Based on available information, night operations for these actions are not anticipated. No additional impacts would result from these actions; therefore, they are not addressed further.

Summary of Effects by Issue Factor by Alternative

Table 143 presents the summary comparison of impacts from each alternative.

Table 143. Summary of effects

Issue Factor	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Issue 8.1: Fractional increase in sky brightness from mine facility and vehicle lighting at Whipple Observatory	No impact, but subject to regional trends and conditions	524% increase in sky brightness at horizon; 28% increase at 10 degrees above horizon; 10% increase at 20 degrees above horizon; 1% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	83% increase in sky brightness at horizon; 8% increase at 10 degrees above horizon; 3.3% increase at 20 degrees above horizon; 0.4% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	Slight increase over Barrel Alternative due to heap leach facilities
Issue 8.1: Fractional increase in sky brightness from mine facility and vehicle lighting at Jarnac Observatory	Same as Whipple	Undetermined increase at horizon due to overlap with light from City of Nogales; 63% increase at 10 degrees above horizon; 22% increase at 20 degrees above horizon; 2% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	Undetermined increase at horizon due to overlap with light from City of Nogales; 21% increase at 10 degrees above horizon; 8% increase at 20 degrees above horizon; 0.7% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	Slight increase over Barrel Alternative due to heap leach facilities

Issue Factor	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Issue 8.1: Fractional increase in sky brightness from mine facility and vehicle lighting at Sonoita	Same as Whipple	363% increase in sky brightness at horizon; 31% increase at 10 degrees above horizon; 12% increase at 20 degrees above horizon; 1% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	76% increase in sky brightness at horizon; 10% increase at 10 degrees above horizon; 4% increase at 20 degrees above horizon; 0.1% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	Slight increase over Barrel Alternative due to heap leach facilities
Issue 8.1: Fractional increase in sky brightness from mine facility and vehicle lighting at Corona de Tucson	Same as Whipple	425% increase at 5 degrees above horizon; 119% increase at 10 degrees above horizon; 31% increase at 20 degrees above horizon; 3% increase at 90 degrees above horizon (project area is blocked by terrain and is therefore provided for closest degree visible above horizon)	Slight increase over Barrel Alternative due to heap leach facilities	28% increase at 10 degrees above horizon; 11% increase at 20 degrees above horizon; 0.1% increase at 90 degrees above horizon (project area is blocked by terrain and is therefore provided for closest degree visible above horizon)	Slight increase over Barrel Alternative due to heap leach facilities	Slight increase over Barrel Alternative due to heap leach facilities
Issue 8.1: Fractional increase in sky brightness from mine facility and vehicle lighting at SR 83	Same as Whipple	Project area was determined to be below the horizon and therefore not measured at horizon; 400% increase at 10 degrees above horizon; 141% increase at 20 degrees above horizon; 25% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	4,000% increase in sky brightness at horizon; 117% increase at 10 degrees above horizon; 39% increase at 20 degrees above horizon; 9% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	Slight increase over Barrel Alternative due to heap leach facilities

Issue Factor	No Action	Proposed Action	Phased Tailings	Barrel	Barrel Trail	Scholefield-McCleary
Issue 8.1: Fractional increase in sky brightness from mine facility and vehicle lighting at Empire Ranch	Same as Whipple	2,530% increase in sky brightness at horizon; 105% increase at 10 degrees above horizon; 32% increase at 20 degrees above horizon; 4% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	1,200% increase in sky brightness at horizon; 24% increase at 10 degrees above horizon; 10% increase at 20 degrees above horizon; 1% increase at 90 degrees above horizon	Slight increase over Barrel Alternative due to heap leach facilities	Slight increase over Barrel Alternative due to heap leach facilities

Note: The issue factor for impacts on dark skies and astronomy is the increase in sky brightness from mine facility and vehicle lighting. Impact analysis measured this as fractional increase in sky brightness for the six night sky analysis points. A summary of the results is provided in this table.

Affected Environment

Relevant Laws, Regulations, Policies, and Plans

Federal

FSM 2300, "Recreation, Wilderness and Related Resource Management," chapter 2380, "Landscape Management," states that mining operations are subject to the rules of 36 CFR 228 Subpart A, "Locatable Minerals," which include requirements for harmonizing mineral operations with scenic values (Part 228.8) and protecting scenic values when approving access to those operations (Part 228.12) (U.S. Forest Service 2003).

Pima County

Pima County and the City of Tucson adopted Final Ordinance No. 2012-14, "2012 City of Tucson/Pima County Outdoor Lighting Code." The purpose of this code is to preserve the relationship of the residents of the city of Tucson and Pima County, Arizona, to their unique desert environment through protection of access to the dark night sky. All outdoor lighting and associated illuminating devices must be specified and installed in conformance with the provisions of the Outdoor Lighting Code under the appropriate permit and inspection. Intended outcomes of the Outdoor Lighting Code include continuing support of astronomy activity and minimizing wasted energy while not compromising the safety, security, and well-being of persons engaged in outdoor nighttime activities.

The Outdoor Lighting Code defines lighting area E1a as "special areas around astronomical observatories and includes all areas within 15 miles of the summit of Kitt Peak and 12.5 miles of the summit of Mount Hopkins, and those areas within any national park, monument, or forest boundary. In these areas, the preservation of a naturally-dark environment, both in the sky and in the visible landscape, is considered of paramount concern."

The Outdoor Lighting code applies to development projects, defined as any residential, commercial, industrial, or mixed-use subdivision plan or development plan that is submitted to the jurisdiction for

approval or for permit. However, under ARS 11-830, mining is exempt from County planning and zoning codes, including the Outdoor Lighting Code.

Existing Conditions

Night Sky Conditions

At present, night sky conditions in the Santa Rita Mountains near the project area are minimally affected by artificial light sources. One exception is the Imerys limestone quarry, located west of the project area near the ghost town of Helvetia. This facility is lit during non-daylight hours. Other than this 22-acre facility, the area in and adjacent to the project area is dark at night, as there are few artificial light sources and no developed areas to affect night sky views or the natural light conditions and cycles that are important to native plants and animals. Background sources of lighting include headlights from vehicles traveling at night along SR 83 and along forest roads. There are no pole-mounted fixtures along those roadways, nor is there lighting in visitor use areas to illuminate their roads, signs, access paths and trails, or parking areas. Sky glow is visible, caused primarily by lighting in the Tucson metropolitan area to the north, with distant sky glow caused by lighting in Nogales and Sierra Vista to the south. The existing sky glow was calculated as described in "An Assessment of the Impact of Potential Mining Operations at the Rosemont Copper Mine on the Night Sky of Southern Arizona" (Dark Sky Partners LLC 2012).

Regionally, there are numerous active hardrock mines throughout the analysis area (e.g., the Mission Complex, Sierrita, Morenci, and Safford mines) and rock quarrying on the Coronado National Forest in the Dragoon Mountains, which potentially contribute to degraded night sky conditions from facility lighting and fugitive dust production. Another ongoing activity that potentially affects night sky conditions is the Stakaer Parsons concrete plant, which produces fugitive dust.

Trends

Regionally, the population of southeastern Arizona continues to increase, and the growth of urban areas contributes to degradation of night sky conditions. However, a recent study at Kitt Peak National Observatory showed that there has been no increase in sky brightness over the past 10 years from regional population growth; this steady-state level is attributed to rigorous enforcement of light shielding ordinances (see the Pima County ordinance above) to prevent or minimize undirected urban light (Dark Sky Partners LLC 2011). An earlier study (Massey and Foltz 2000) showed that the night sky brightness was essentially identical at Kitt Peak National Observatory and the Whipple Observatory. Other regional trends that could affect night sky conditions would be regional population growth, which requires lighted residences and infrastructure (such as residential and commercial access roads, power lines, and telecommunication towers and lines).

Environmental Consequences

Direct and Indirect Effects of Each Alternative

The lighting of the major mine features (the mine pit, processing facility, heap leach pad, and primary access road) would not change because of mine safety needs, nor could these mine features be constructed in a substantially different (and more advantageous) location to reduce sky glow impacts. Thus, the night lighting impacts would be the same for all action alternatives.

Brightness impacts on night skies for the viewpoints are described by identifying how an observer at a viewpoint would or would not be able perceive the increase of brightness when looking toward the

horizon in line with the project area. Brightness from the project area diminishes as the observer increases the angle above the horizon until viewing the zenith (90 degrees from the horizon, or directly overhead). The angle above the horizon at which the observer would cease to notice an increase in brightness from the project area is identified for each viewpoint.

No Action Alternative

Under the no action alternative, the Rosemont Copper Mine would not be constructed or operated in the Santa Rita Ecosystem Management Area and would not produce sky glow or night light pollution within the region or on the Coronado National Forest. Night sky conditions would continue to be affected by the existing conditions and trends discussed above, including night lighting of the Imerys quarry near the project area.

Impacts Common to All Action Alternatives

All of the action alternatives would increase night brightness and impact night viewing and astronomy. The extent differs somewhat by alternative, with large differences between the proposed action and the remaining action alternatives, and a somewhat smaller difference between the Barrel Alternative and the Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives. Details pertaining to those differences and their relative impacts follow. The increased lighting from the action alternatives could overlap with the night lighting from the Imerys quarry, thereby affecting a slightly greater cumulative area. Refer to the "Biological Resources" resource section in this chapter for additional information.

Any substantial increase in sky glow or sky brightness (i.e., a more than approximately 10 percent increase over existing levels) would have direct, adverse impacts on dark skies because natural light conditions and cycles required for plant and animal species would be altered and because night sky viewing would be impaired for naked-eye viewers. Therefore, all action alternatives would have direct, adverse, long-term impacts to night sky viewing until mine closure. The impacts that the increases in sky glow described below would have on the astronomy industry are analyzed in the "Socioeconomics and Environmental Justice" resource section.

The region's astronomy observatories would be affected by sky brightening to a substantial, adverse degree in the long term until mine closure because the "useful" regions of the sky for astronomy extend from the zenith to 20 degrees from the horizon (70 degrees from zenith).

Direct and Indirect Effects of Each Alternative

The revised Rosemont Copper Project lighting plan would be applicable to the Barrel Alternative, Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives. The heap leach and associated oxide ore processing facilities were not included in the Barrel Alternative and subsequently were not included in the revised lighting and revised model analysis. However, these facilities would contribute up to an additional 105,538 additional lumens for the Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives with zero direct uplight (Dark Sky Partners LLC 2012). This amount of additional lighting represents an increase of about 1.6 percent in total lighting, translating into a very small increase in sky glow as seen from all observing sites. The original lighting plan would apply to the proposed action only.

The results of the night sky computer modeling of current conditions, with the addition of Rosemont Copper Mine lighting, show that sky glow would increase at all of the analysis viewpoints, although

to varying degrees (Dark Sky Partners LLC 2011). The revised lighting plan, as applied to the Barrel, Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives, would have a significantly reduced impact to night skies from the viewpoints, compared with the original lighting plan for the proposed action. For all actions, the impacts of Rosemont Copper Project night lighting as seen from the analysis viewpoints are discussed below. Note that sky brightness would vary, depending on the angle of view above the Rosemont Copper Mine site: the higher the angle of view, the lower the intensity of sky brightness or sky glow from light dispersion and dissipation. Table 144 provides a comparative analysis of the lumens and uplight fraction that would be produced at night under the original lighting plan for the proposed action and under the revised lighting plan for the other action alternatives. Table 145 provides the lumens and uplight fraction produced at night by towns and cities in southern Arizona and Sonora, Mexico, for further comparative points of reference.

Table 144. Comparison of light source locations and outputs

Location	Lumens Original Lighting Plan	Uplight Fraction Original Lighting Plan	Lumens Revised Lighting Plan	Uplight Fraction Revised Lighting Plan
Rosemont Copper Mine Site				
Ore processing area	4,911,990	0.000	2,605,780	0.00*
Mine pit	3,660,690	0.300	1,514,366	0.300*
Entry road/In-plant roads	3,374,135	0.000	218,840	0.00
Leach field	5,964,300	0.300	105,538 (except Barrel Alternative)	0.0
Dry-stack conveyor	3,744,240	0.000	1,924,660	0.00
Vehicles	160,000	0.110	160,000	0.11
Total	**21,815,355**		**6,529,184 (6,423,646 for the Barrel Alternative)**	

Sources: Dark Sky Partners LLC (2011); M3 Engineering and Technology Corporation (2011).

* Uplight fraction is not identified in the revised modeling report for ore processing area and mine pit, so it is assumed to have the same uplight fraction as the original lighting plan.

Table 145. Comparison of light sources of towns and cities in southern Arizona

Location	Population	Total Lumens	Uplight Fraction
Tucson/Eastern Pima County	1,050,000	1,795,500,000	0.082
Nogales, Sonora, Mexico	160,000	273,600,000	0.100
Nogales, Arizona	19,573	33,469,830	0.100
Benson	4,833	8,264,430	0.100
Sonoita	910	1,556,100	0.100
Tubac	2,000	3,420,000	0.100
Sierra Vista	43,320	74,077,200	0.100

As mentioned above, the computer model was used to calculate the increase in sky brightness as a percentage of existing night sky conditions. To help understand the visual impact of the percentages in the following subsections, readers should be aware that a 10 percent increase in brightness is only perceptible to most people when the two sources of light can be directly compared, with one appearing directly adjacent to the other. In this sense, a 10 percent increase in brightness may seem to

be only just perceptible. A 50 percent increase of brightness would be perceptible to most observers (Dark Sky Partners LLC 2011).

Proposed Action Alternative

All impacts for the proposed action are based on the 2010 computer modeling analysis for the original lighting plan (Dark Sky Partners LLC 2010).

Whipple Observatory Viewpoint

Sky brightness intensity would vary, depending on the angle above the Rosemont Copper Mine site. Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 1 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky glow would increase by 10 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 28 percent. At the horizon (89 degrees from zenith), sky glow would increase by 524 percent and would be clearly visible.

Jarnac Observatory Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 2 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky glow would increase by 22 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 63 percent and would become clearly perceptible to the average naked-eye viewer. At the horizon (89 degrees from zenith), sky glow from the mine facilities would combine with the existing sky glow from Nogales, Arizona.

Sonoita Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 1 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky glow would increase by 12 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 31 percent. At the horizon (89 degrees from zenith), sky glow would increase by 363 percent and would be clearly visible to the average naked-eye viewer.

Corona de Tucson Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 3 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon, sky brightness would increase by 31 percent over current conditions. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 119 percent and would be clearly visible to the average naked-eye viewer. At the horizon (85 degrees for this viewpoint due to approximated blocking terrain in the 2010 analysis), sky brightness would increase by approximately 425 percent over current conditions.

State Route 83 Viewpoint

Sky brightness directly overhead at the zenith (90 degrees from the horizon), as viewed from the highway (at 4.5 miles from the mine site), would increase by 25 percent over existing conditions due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky brightness would increase by 141 percent and would be clearly visible to the average naked-eye viewer. Sky brightness at 5 degrees over the mine site (85 degrees from zenith due to approximated blocking terrain in the 2010 analysis) would increase by more than 400 percent over existing conditions.

Empire Ranch Viewpoint

From Empire Ranch, sky brightness directly overhead at the zenith (90 degrees from the horizon) would increase by 4 percent over existing conditions due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky brightness would increase by 32 percent over existing conditions. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 105 percent and would be clearly visible to the average naked-eye viewer. At the horizon, sky brightness would increase by 2,530 percent over current conditions and would be clearly visible from this location.

Phased Tailings Alternative

The impacts would be the same as discussed under the Barrel Alternative because the same revised project lighting plan would be followed, with one exception. The addition of a heap leach for this alternative would add 105,538 lumens, or 1.6 percent additional lighting. Due to the relatively small increase in lighting that this would represent, this alternative with the heap leach was not individually modeled.

Barrel Alternative

All impacts for the Barrel Alternative are based on the 2012 computer modeling analysis for the revised lighting plan (Dark Sky Partners LLC 2012).

Whipple Observatory Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 0.4 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky glow would increase by 3.3 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 8 percent. At the horizon (89 degrees from zenith), sky glow would increase by 83 percent and would be visible.

Jarnac Observatory Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 0.7 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky glow would increase by 8 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 21 percent and would become clearly perceptible to the average naked-eye viewer. At the horizon (89 degrees from zenith), sky glow from the mine facilities would combine with the existing sky glow from Nogales, Arizona.

Sonoita Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 0.1 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky glow would increase by 4 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 10 percent. At the horizon (89 degrees from zenith), sky glow would increase by 76 percent and would be visible to the average naked-eye viewer.

Corona de Tucson Viewpoint

Directly overhead at the zenith, 90 degrees from the horizon, sky glow would increase by 0.1 percent over current conditions at this location due to mine lighting. At 20 degrees above the horizon, sky

brightness would increase by 11 percent over current conditions. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 28 percent. The updated terrain parameters of the model for the revised lighting plan indicate that the terrain would block mine lighting up to 8 degrees above the natural horizon; therefore, impacts were modeled at 10 degrees from horizon.

State Route 83 Viewpoint

Sky brightness directly overhead at the zenith (90 degrees from the horizon), as viewed from the highway (at 4.5 miles from the mine site), would increase by 9 percent over existing conditions due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky brightness would increase by 39 percent. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 117 percent and would be visible to the average naked-eye viewer. Sky brightness at 2 degrees over the mine site (88 degrees from zenith due to updated terrain blocking data in the 2012 analysis) would increase by more than 4,000 percent over existing conditions due to the proximity of the highway to the viewpoint and would be clearly visible to the average naked-eye viewer.

Empire Ranch Viewpoint

From Empire Ranch, sky brightness directly overhead at the zenith (90 degrees from the horizon) would increase by 1 percent over existing conditions due to mine lighting. At 20 degrees above the horizon (70 degrees from zenith), sky brightness would increase by 10 percent over existing conditions. At 10 degrees above the horizon (80 degrees from zenith), existing sky glow would increase by 24 percent. At the horizon, sky brightness would increase by approximately 1,200 percent over current conditions and would be clearly visible to the average naked-eye viewer.

Barrel Trail Alternative

The impacts would be the same as discussed under the Barrel Alternative because the same revised project lighting plan would be followed, with one exception. The addition of a heap leach for this alternative would add 105,538 lumens, or 1.6 percent additional lighting. Due to the relatively small increase in lighting that this would represent, this alternative with the heap leach was not individually modeled.

Scholefield-McCleary Alternative

The impacts would be the same as discussed under the Barrel Alternative because the same revised project lighting plan would be followed, with one exception. The addition of a heap leach for this alternative would add 105,538 lumens, or 1.6 percent additional lighting. Due to the relatively small increase in lighting that this would represent, this alternative with the heap leach was not individually modeled.

Cumulative Effects

This cumulative effects discussion addresses the cumulative impacts of the action alternatives and any applicable reasonably foreseeable actions as identified on the Coronado ID team's list of reasonably foreseeable future actions, provided in the chapter 3 introduction. Along with present actions (such as the Imerys quarry night lighting) and the actions associated with the proposed Rosemont Copper Project, the following reasonably foreseeable actions from that list were determined to contribute to a cumulative impact to dark skies:

- Development of the Farmers Investment Company property within the Town of Sahuarita's jurisdiction over the next 40 to 50+ years for residential and commercial mixed use is proposed, along with the enhancement of more than 12 miles of the Santa Cruz River in both the town of Sahuarita and Pima County.
- Rancho Sahuarita is a proposed 3,048-acre planned community located within the Town of Sahuarita's jurisdiction adjacent to the northwestern portions of the Sahuarita Farms property. The plan allows for 11,680 residential dwelling units, or 3.8 residents per acre. The plan also includes about 1,000 acres of mixed-use and/or other non-residential land uses.
- Quail Creek is a proposed 1,700-acre master-planned retirement community located northeast of Sahuarita Farms' southernmost specific plan parcel. The community is within the Town of Sahuarita's jurisdiction and is entitled for approximately 5,000 housing units and a limited amount of nonresidential uses adjacent to Old Nogales Highway.
- Madera Highlands is a proposed 920-acre community located within the Town of Sahuarita's jurisdiction. The plan allows for approximately 3,500 units, or approximately 3.8 residents per acre. It is located adjacent to the eastern boundary of Sahuarita Farms' southernmost development parcel.

Reasonably foreseeable future actions that could cumulatively affect night lighting would be regional population growth, as indicated by the Farmers Investment Company land use plans and Rancho Sahuarita, Quail Creek, and Madera Highlands master-planned communities within the town of Sahuarita. Combined, these master-planned communities would add more than 21,000 residential dwelling units on approximately 5,600 acres of currently non-residential-use lands and more than 1,000 acres of commercial mixed-use development over the next 40 to 50 years. These developments would be subject to the Pima County Outdoor Lighting Code in order to reduce impacts of urban development on night skies. These actions, including those ongoing activities and trends described under the "Affected Environment" part of this resource section, would have potentially adverse impacts on night lighting and dark skies and on astronomy research because they would potentially contribute to sky glow and light pollution. While the Pima County Outdoor Lighting Code currently keeps light pollution at levels that do not adversely affect astronomy research, the trend toward increasing urban and industrial development and mineral resource exploration, development, and extraction would adversely impact night skies in terms of the nighttime light levels required for astronomy research.

Climate Change

Anticipated changes to the climate of southern Arizona are not expected to contribute to impacts to dark skies.

Mitigation Effectiveness

Mitigation and Monitoring – Forest Service

- **Implementation of an outdoor lighting plan that would reduce potential impacts from artificial night lighting.** Adherence to the "Rosemont Copper Project Light Pollution Mitigation Recommendation Report" (Monrad et al. 2012a) would be required for the Barrel, Phased Tailings, Barrel Trail, and Scholefield-McCleary Alternatives. This lighting plan would reduce impacts to night lighting and darks skies through the use of LED lights with spectral controls to minimize lighting in the blue part of the light spectrum and shielding/beam control on nonfixed lights to minimize direct uplight. This lighting plan could

also be applied to the proposed action should this alternative be chosen and use of the plan be included as a requirement of the record of decision (ROD).

Mitigation and Monitoring – Other Regulatory and Permitting Agencies

- **A variety of dust control measures,** as identified under air quality in appendix B and addressed in the "Air Quality and Climate Change" resource section of this chapter, would reduce fugitive dust and, subsequently, the uplight reflection of mine lighting from dust during nighttime operations. Specifically, roads, material transfer points, and processing areas would be treated with dust control agents, water sprays, physical covers, and wind barriers. Acid leaching on the heap leach pile would use drip emitters to prevent or minimize aerosol production and losses to wind (for all action alternatives except Barrel). Refer to the "Air Quality and Climate Change" resource section of this chapter and appendix B for further information on dust control mitigation and its effectiveness.

Conclusion of Mitigation Effectiveness

Implementing the revised lighting plan would significantly reduce mine lighting impacts to dark skies, compared with the original lighting plan. The revised lighting plan's reduction of lighting impacts is described in the "Environmental Consequences" discussion in this resource section. In summary, the revised lighting plan would reduce total lumens produced by the mine to 6,423,646 lumens for the Barrel Alternative from 21,815,355 for the proposed action under the original lighting plan. Sky glow under the revised lighting plan would be significantly reduced for all viewpoints at all zeniths, compared with sky glow that would occur under the original lighting plan. However, even with the revised lighting plan's reduction of lighting impacts, mine lighting would have a long-term, adverse impact on dark skies during the premining and active mining phases.

Implementing dust control measures would have minor, long-term, beneficial impacts on dark skies by reducing potential light dispersion by atmospheric particles and aerosols during the lifetime of the proposed project.