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Subject	Twin Pines Minerals, LLC Saunders Demonstration Mine Analysis of Night Lighting Issues
Attention	Lewis Jones/Jones Fortuna LP
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1. Introduction

Twin Pines Minerals, LLC proposes to mine heavy mineral sands from a 582-acre site located approximately 3 miles west of St. George in Charlton County, Georgia. The mining operation involves excavating mineral-bearing sands from a pit that is approximately 100 feet wide that advances at an average rate of 115 feet a day. Mining of the site is estimated to take 4 years to complete. A conveyor system will transport the excavated materials from the mining pit to a wet concentration plant located to the east of the mining area. After the heavy minerals have been removed from the sand, a conveyor will move the tailings back to the excavation site, where they will be used to refill the excavated area that will then be restored. The heavy minerals extracted at the wet concentration plant will be transported to a mineral separation plant located to the southeast of the mined area, at the site of the former chip mill located on the south side of SR-94. After final separation, the minerals will be shipped by truck or by rail from a rail loadout facility to be developed on the existing Georgia Southern and Florida rail line that is located to the immediate south of mineral separation plant site.

As indicated on Figure 1, the proposed Saunders Demonstration Mine site and its associated processing facilities are located approximately 2.8 miles to the southeast of the southeastern boundary of the Okefenokee National Wildlife Refuge and 24.7 miles southeast of Stephen C. Foster State Park, which is located within the Wildlife Refuge in the area near the refuge's west entrance. The mine site also lies within 2.8 miles from the closest boundary of the Okefenokee National Wilderness Area, a federally designated wilderness area located within the boundaries of the Wildlife Refuge, which encompasses a large portion, but not all the land in the Wildlife Refuge. In response to the mine proposal, members of the public and advocacy groups have raised concerns about the nighttime lighting that will be needed at the proposed mine, questioning whether it could have adverse effects on night skies conditions at Stephen C. Foster State Park, which is a designated International Dark Sky Park. Further concerns were brought up about the effects of lighting on wildlife and the experience of visitors to the Wilderness Area. The purpose of this memorandum is to provide background for understanding the issues, document the lighting that the operation of the mine will require to meet dark sky conventions, and assess the extent to which this lighting could have adverse effects on night skies conditions at the Stephen C. Foster State Park or on nighttime lighting conditions within the Okefenokee National Wilderness Area.

2. Background

2.1 Night Sky Conditions in the Okefenokee National Wildlife Refuge, Okefenokee National Wilderness Area, and Stephen C. Foster State Park

The Okefenokee National Wildlife Refuge (see Figure 1) is a 630-square-mile area under the jurisdiction of the U.S. Fish and Wildlife Service (USFWS) that encompasses most of the Okefenokee Swamp, a large, shallow swamp that is considered to be the largest blackwater swamp in North America. A 533-square-mile area within the Wildlife Refuge has been designated as a National Wilderness Area, a class of area established by the Wilderness Act of 1964 in which human activities are strictly limited to permit ecosystems to evolve over time without human intervention, and to provide opportunities for solitude and for recreation in an undisturbed natural setting. Stephen C. Foster State Park is a 120-acre area that lies within the Wildlife Refuge in an area near its West Entrance that is not a part of the Wilderness Area.

The nighttime skies above the Wildlife Refuge, Wilderness, and State Park have unusually low levels of skyglow (Light Pollution Map, 2020). Skyglow is the term used to refer to the glow in the night sky caused by diffused light in the atmosphere. Skyglow reduces the contrast in the night sky, interfering with the ability to see stars and planets at night. In an article titled "Dissecting Light Pollution," Arthur Upgren (1996) indicates that even in the most pristine environments, the night sky has a minimum surface brightness that is created by a combination of "…faint airglow in the upper atmosphere (a permanent low grade aura), sunlight reflected off interplanetary dust (zodiacal light), starlight scattered in the atmosphere, and background light from faint unresolved stars and galaxies."

In the skies above cities and in the regions extending many miles out from urban areas, levels of skyglow are considerably higher than the natural levels because of the effects of artificial lighting. In these areas, skyglow levels are affected by light that escapes directly into the sky because of light fixtures that are not properly directed and shielded, and to a lesser degree by light reflected upward from illuminated surfaces. Upgren (1996) notes that typical suburban skies are about 5 to 10 times brighter than the natural sky and that in city centers, nighttime skies can be 25 to 50 times brighter than the natural sky background.

A major factor contributing to the darkness of the night skies in the Wildlife Refuge, Wilderness Area, and State Park is that the Okefenokee Swamp is a large natural area with very little development and thus nearly no nighttime artificial lighting. In addition, the swamp is somewhat distant from populated areas where there are concentrations of lights that can create skyglow. The relationship of the Wildlife Refuge, Wilderness Area, and State Park to concentrations of light in the surrounding region can be seen on Figure 2, a 2016 nighttime view of the Earth created by the NASA Goddard Space Flight Center's Terrestrial Information Center Laboratory based on imagery taken by the Suomi National Polar-orbiting Satellite. The lightest grid cells, such as those seen in the centers of cities like Jacksonville, Brunswick, Waycross, and Valdosta, indicate the areas with the highest levels of nighttime illumination. The grid cells that are light brown and dark brown in color indicate areas where there are concentrations of nighttime lighting, but where the overall levels of illumination are lower. Figure 3 is a map based on the same data that focuses in on the sources of light in closest proximity to the Wildlife Refuge, Wilderness Area, and State Park on the east and south.

The communities closest to the Stephen C. Foster State Park, which is located near the middle of the Okefenokee swamp, are:

- Fargo, a community of approximately 320 located 17 miles to the west
- Folkston and the adjacent community of Homeland that are located approximately 21 miles to the east and have a combined population of approximately 3,400

- Waycross, a community of approximately 13,500 located 31 miles to the north

The largest source of nighttime light pollution in the region is the Jacksonville metropolitan area with a population of approximately 1.5 million, the center of which is located approximately 53 miles southeast of the state park.

When nighttime sky conditions in Stephen C. Foster State Park were documented in 2016, light domes were observed on the horizon that were associated with light emanating from Waycross on the north and Jacksonville on the southeast (DNR, 2016). It is important to note that no light dome was associated with Folkston and Homeland, 21 miles to the east, which besides having a combined resident population of 3,400, is the site of the D. Ray James Correctional Facility, which in 2016 housed a population of approximately 1,500 prisoners. At that time, this facility would have been a major emitter of light into the night sky because the site has 46 tall poles, most of which are used to support four floodlights that appear to be 400 Watt, 38,000 lumen fixtures that do not have a cutoff design to prevent skyglow impacts from light that beams directly into the sky.

Scientists have adopted a scale for rating night sky darkness conditions known as the Bortle Scale (Bortle, 2001). This scale rates nighttime darkness conditions in terms of the degree to which they permit celestial features to be observed. The scale ranges from Class 1: Excellent Dark Sky Site where there is essentially no light pollution, which permits maximum visibility of the stars, to Class 9: Inner City Sky, where the night sky is brightly lit by light pollution, making it impossible to see many stars and constellations. Maps documenting dark skies conditions identify the Okefenokee Wildlife Refuge and Wilderness Area and the Stephen C. Foster State Park as lying within an area with a Class 2 Bortle rating (Light Pollution Map 2020), which the scale characterizes as a “Typical Truly Dark Site” where light pollution is relatively minor, and most celestial features are readily visible.

The dark skies conditions at Stephen C. Foster State Park have become one of its recognized attractions (DNR, 2020), and the park management has instituted programs that build on the favorable conditions for stargazing, including nighttime astronomy programs that make use of two large telescopes that have been installed on the site, and evening paddle and boat trips on the lakes to permit sky viewing. In 2016, Stephen C. Foster State Park applied for and received designation from the International Dark-Sky Association as an International Dark Sky Park (DNR, 2016). DarkSky International (DSI) (formerly International Dark Sky Association) is an organization established to protect night skies from light pollution. Its approach is to educate, guide strategy, monitor results, and support aligned actions among DSI chapters, volunteers, and other stakeholders. Its goal is to provide leadership, tools and resources for individuals, policymakers, and industry to reduce light pollution and promote responsible outdoor lighting (DSI, 2020a). One of DSI’s programs is designation of International Dark Skies Parks (IDSP), which DSI defines as “…a land possessing an exceptional or distinguished quality of starry nights and a nocturnal environment, and that is specifically protected for its scientific, natural, educational, and/or cultural heritage resources, and/or for public enjoyment.” (DSI, 2018). The goals for establishment of a dark sky park include:

- To promote protection of the natural nighttime environment, public enjoyment of the night sky and its heritage, and/or areas ideal for professional and amateur astronomy
- To encourage conservation professionals to recognize dark skies as a valuable resource in need of proactive protection
- To encourage parks and similar public entities to become environmental leaders on dark sky issues by communicating the importance of dark skies to the general public and surrounding communities, and by providing an example of what is possible with proper stewardship

To be eligible for designation as an IDSP, a long list of requirements must be met. One of the most important of these is that the candidate site must document that its nighttime skies meet specific criteria. IDSP guidelines specify that the Milky Way is readily visible to the unaided eye on a typical night. These conditions correspond approximately to a visual-band zenith luminance of 21.2 magnitudes per square arcsecond or greater and the naked eye limiting magnitude (NELM) of +6. To substantiate the sky quality, measurements of the night sky brightness at the zenith must be made with suitable instruments, or the NELM estimated by a qualified observer. …Further, panoramic nighttime photography of the horizon must be included to substantiate the number and extent of light domes visible from the site. …Any designated IDSP that no longer meets these conditions but documents a visual-band zenith luminance from 20.0 to 21.19 magnitudes per square arcsecond or a naked-eye limiting magnitude (NELM) no higher than +5 will be included in a List of Endangered IDSP Sites published on the DSI website. DSI reserves the right to suspend or revoke the IDSP designation of a park with night sky quality that falls below a visual-band zenith luminance of 20.0 magnitudes per square arcsecond or a naked-eye limiting magnitude (NELM) of +5 (DSI, 2018)."

To ensure the Milky Way is potentially visible, the following steps are recommended by DSI:

- Minimize artificial light sources yielding significant glare in the vicinity of the site; and
- Ensure that any light domes present are dim, restricted in extent, and close to the horizon.

Other requirements for eligibility for designation as an IDSP include a commitment to adopt a lighting plan that brings the majority of the lighting at the park into conformance with DSI's dark-sky compliant lighting standards, to monitor lighting conditions in the park to ensure they remain in compliance with the IDSP eligibility criteria, to conduct dark skies education and outreach programs, and to file an annual report (DSI 2018 pp 6-8).

DSI's visual-band zenith luminance threshold for Dark Sky Park sites is expressed in terms of magnitudes per square arcsecond. The magnitude per square arcsecond measurement unit is used by astronomers to measure the brightness of surfaces. These measurements are made using small, inexpensive hand-held Sky Quality Meters. The higher the magnitudes per square arcsecond reading, the darker the sky. The darkest skies have magnitudes per square arcsecond readings of 22.0, reflecting conditions where there is no pollution by artificial light and moon's brightness is average. A reading of 21.0 is associated with rural areas that are not far from medium sized cities. Further down the night sky darkness scale, readings of 17.0 are typical for the skies near the centers of large cities (Flanders, 2008). DSI's visual-band zenith luminance threshold of 21.2 magnitudes per square arcsecond thus requires a site to be in an area where the sky's level of darkness is in the range between that of rural areas with somewhat darker than normal skies and areas where the darkness of the sky is not affected by artificial light.

The application for IDSP status that the Stephen C. Foster State Park submitted in 2016 documented an initial visual-band zenith luminance of 21.54 magnitudes per square arcsecond (0.4 mcd/m2). This sky darkness reading placed the park above the threshold of 21.2 magnitudes per square arcsecond that qualification for IDSP status requires. After the park implemented its plan for the mitigation of the impacts of the lighting located in the park, the visual-band luminance levels increased to 21.62 and 21.87 indicating the success of the park's light impact mitigation measures in improving the level of darkness of the sky seen above the site. (DNR, 2016). The annual IDSP reports that the park filed with DSI in 2018 2019, 2020, and 2021 made no reference to more recent observations of the park's night sky viewing conditions or measurements of visual-band zenith luminance (DNR, 2018, 2019, 2020, 2021).

2.2 Nighttime Darkness Conditions in the Okefenokee National Wildlife Refuge, Okefenokee National Wilderness Area, and Stephen C. Foster State Park

For a number of reasons, nighttime conditions in the Wildlife Refuge and Wilderness Area are expected to be very dark. The nighttime lighting within the Wildlife Refuge is primarily restricted to the lighting at Stephen C. Foster State Park, and a flashing light on a radio tower at the south end of the State Park. Because the impacts of the lighting at the State Park have been attenuated through the park's lighting management plan, and because sources of light outside the Wildlife Refuge are very far away, the Wildlife Refuge, Wilderness Area, and State Park are all very dark at night, particularly after the 10:00 p.m. curfew at the park when activities and lighting are restricted. Because of these circumstances, the wildlife in the Wildlife Refuge as well as any visitors who might be spending the night in areas of the Refuge outside the State Park experience dark conditions.

Relatively few people experience the nighttime darkness of the Wildlife Refuge and Wilderness Area. The Wildlife Refuge's entrances close at 5:30 p.m. from November 1 to February 28 and at 7:30 p.m. from March 1 to October 31. The primary concentration of nighttime visitors is at Stephen C. Foster State Park where there are 9 cottages; 66 tent, trailer, and RV campsites; and a pioneer campsite for groups of up to 50. Any visitors who are not staying overnight at the State Park but who stay after the Wildlife Refuge's gates close to attend the State Park's nighttime events, are required to leave the State Park and Wildlife Refuge by 10:00 p.m. The statistics in the State Park's 2021 report to DSI indicate that in 2021, the total number of visitors who participated in the park's nighttime programs over the course of the year was 0 due to COVID restrictions. (DNR, 2021). In the other areas of the Wildlife Refuge and Wilderness, overnight visitors are limited to camping at the 10 designated overnight shelters and camping sites at the locations identified on Figure 1. These sites can be accessed only by use of boats on the boat trails. A system that requires advance reservations for the use of these sites limits the use of these sites to a single group per night, and the total number of users in a group to no more than 20 (USFWS, 2020).

3. Description of the Project's Proposed Nighttime Lighting

The first step in determining whether and the extent to which the lighting used by the proposed mine project might affect dark skies conditions at Stephen C. Foster State Park and might affect wildlife and the experience of visitors in the Wildlife Refuge and Wilderness Area is to consider the physical relationship of the project site to the Wildlife Refuge, Wilderness Area, and State Park, and to inventory the kinds of lighting that will be in use at each of the project's facilities.

Figure 1 depicts the location of the proposed Saunders Demonstration Mine project site in relationship to the boundaries of the Okefenokee National Wildlife Refuge, Okefenokee National Wilderness Area, and Stephen C. Foster State Park.

Figure 4 is a site plan of the proposed mine project that highlights the locations where nighttime lighting will be required to support the project's 24-hour-a-day operation. As this map indicates, most of the project site will not be illuminated. The lighting required to support nighttime operations will be restricted to relatively small areas at the specific locations called out by the text in the white boxes on the figure.

3.1 Project Lighting Design

To minimize lighting impacts, DSI recommends developing a detailed lighting plan following guidelines for dark skies friendly lighting design established by DarkSky International (DSI 2018, 202b), which include the following:

- Lights should be left on only when required.
- Lighting should be limited to areas requiring illumination.
- Lights should be no brighter than necessary.
- Light bulbs should be selected to minimize blue-light emissions (those with a color temperature of over 3000 Kelvin), which brighten the sky more than other colors of light.
- Fixtures should be shielded to direct light where it is needed without contributing skyglow or shining outside of the project's boundaries.

DSI provides examples of fixtures that provide appropriate levels of shielding, and it maintains a database of fixtures bearing the Dark Sky Friendly Seal of Approval (DSI, 2020c). We recommend that any fixtures installed at the site be selected from this list.

3.2 Lighting Requirements by Area

The lighting required to support the activities at the locations identified on Figure 4 is described in this section. This preliminary plan provides for 40 light fixtures to be installed on the conveyor belts. These lights will be motion-activated so they will turn on only when there is motion in their vicinity. All other lights at the facility will be controlled with a photocell that will turn them on at dusk and off at dawn.

3.2.1 Mining Area

Although the mining area encompasses approximately 582 acres, only a very small portion of this area will be illuminated at any one time. As shown by the colored bands on Figure 4, mining of the site will proceed systematically over an estimated 4-year period. During this time, the area being actively excavated will consist of a trench approximately 100 feet wide and 500 feet long. Because the excavated area will be refilled as the mining process proceeds, the location of the active mining pit will shift over time, but its dimensions will remain the same. The material from the mine will be excavated using a dragline, which is essentially a large crane used for digging and dumping. To illuminate the nighttime mining activities, four lights will be located on the dragline's boom, one will be mounted on each side of the dragline's cab, two will be mounted on the rear of the cab, and two will be mounted underneath the counterweight. These lights will illuminate a work area approximately 100 to 150 feet in diameter. Because the location of the work area will shift over time, the distance of this area from the Wildlife Refuge, Wilderness Area, and State Park will also shift over time as well. At its closest, when the excavation is taking place in the mining area's northwest corner during Year 4, the excavation area will be 2.8 miles from the boundary of the Wildlife Refuge and Wilderness Area, and 24.7 miles from Stephen C. Foster State Park. At its farthest, when the excavation is taking place in the southeast corner of the mining area during Year 1, these distances will be 4.3 and 26 miles, respectively.

3.2.2 Conveyor Systems

Two conveyor systems will extend from the area being excavated to the wet concentration plant. One will transport the mined material to the wet concentration plant and the other will transport the back to the excavation, where they will be returned. As mentioned above, the two conveyor belts will be illuminated with a total of up to 40 flood lights, but these lights will be individually controlled by motion sensors to ensure they turn on only when necessary to inspect or perform maintenance on a specific segment of a conveyor.

3.2.3 Wet Concentration Plant

The wet concentration plant will be illuminated with up to 70 light fixtures. Some of the fixtures will be located in the circulation and outdoor storage areas around the plant, but the majority will be located within the plant, which will be a several-story open structure. The wet concentration plant is located 4.1 miles from the closest boundary of the Wildlife Refuge and Wilderness Area, and approximately 26 miles from Stephen C. Foster State Park.

3.2.4 Fuel Storage Area

A fuel storage area will be located on the wet concentration plant access road, halfway between SR-94 and the wet concentration plant. It will be illuminated by four light-emitting diode (LED) floodlights. These lights will be motion-activated so that they will only be on at times when the fuel storage area is being used. This facility is located approximately 4 miles from the closest boundary of the Wildlife Refuge and Wilderness Area, and approximately 26.3 miles from Stephen C. Foster State Park.

3.2.5 Mineral Separation Plant

The mineral separation plant will be located southeast of the mining area and south of SR-94 at a site formerly used as a wood chip mill. Much of the lighting that illuminated this site when the chip mill was in operation is still in place. These lights are controlled by photocells and continue to go on every night, even though the chip mill is no longer operating. These existing lights will be supplemented by additional lights mounted on the exterior walls of the mineral separation plant building. In addition, lights will be installed at a weigh scales and truck loading area, a train loadout facility, in the vicinity of office buildings and in a parking area. The mineral separation plant site is located 5.2 miles from the closest boundary of the Wildlife Refuge and Wilderness Area, and approximately 26.7 miles from Stephen C. Foster State Park.

4. Assessment: Potential of the Lighting at the Proposed Mine to Affect Nighttime Lighting Conditions in the Okefenokee National Wildlife Refuge, Okefenokee National Wilderness Area, and Stephen C. Foster State Park

4.1 Overview

Provided the recommendations set forth above are followed, the project will have very little potential to contribute to skyglow, create glare effects, or spill light into areas outside the project boundary. Because of the distance of the project's lighted areas from the boundaries of the Wildlife Refuge and Wilderness Area and from Stephen C. Foster State Park, the project's lighting will have no direct effect on wildlife within the Wildlife Refuge and Wilderness Area, and no effect on the experience of visitors in these areas. In addition, a numerical analysis applying Walker's Law very clearly establishes that the project's effect on the night sky conditions in Stephen C. Foster State Park will be extremely small. To the extent any impact is even detectable, it will be insignificant.

4.2 No Impacts on Wildlife and the Experience of Visitors in the Wildlife Refuge and Wilderness Area

The mine project's lighting will have no effect on wildlife and the experience of visitors in the Wildlife Refuge and Wilderness Area for several reasons. The first is that because of the efforts that will be made to specify lighting that focuses the light where it is needed for operations and avoid allowing light to spill into the sky and the surrounding area, little to none of the light will shine out of the site in directions that

would be visible from the Wildlife Refuge and Wilderness Area. In addition, even if some of the light were to escape from the site and shine in the direction of the Wildlife Refuge and Wilderness Area, it would not be visible from these areas because of the heavy tree cover within the Wildlife Refuge and Wilderness Area and in the 2.9- to 5.2-mile-long landscape segments between the boundaries of these areas and the project's illuminated facilities. An additional variable to consider is that even if in the unlikely circumstances that lighting from the project's facilities were to reach the boundaries of the Wildlife Refuge and Wilderness Area, it would not likely affect ambient lighting conditions. This is because light energy or illumination decreases at a rate equal to the square of the distance, and as a consequence, detectable impacts on ambient lighting conditions are generally limited to areas that are close to the light source. Given all these factors, there is essentially no potential for light from the project to extend into the boundaries of the Wildlife Refuge and Wilderness Area and have an effect on the wildlife within these areas. Similarly, there is no potential for light from the project to extend into the boundaries of the Wildlife Area and Wilderness Refuge where it would be seen by and affect the experience of overnight visitors, the closest of whom would be at the Monkey Lake Overnight Shelter, 10.6 miles from the project area.

4.3 Insignificant Effects on Dark Skies Conditions at the Stephen C. Foster State Park

To put the potential effects of the lighting at the proposed mine project on dark skies conditions at the Stephen C. Foster State Park into perspective, several numerical analyses were undertaken.

The first step was to calculate the total numbers of lumens of light proposed for installation at the project. In consultation with the project's engineers, the numbers of fixtures with lamps of varying lumen outputs proposed for each of the facilities on the project site were identified. Using this information, a spreadsheet summarizing this information and calculating the numbers of lumens at each of the project's facilities and the total lumens for the project as a whole was prepared. A copy of this spreadsheet is provided in Appendix 1. This analysis determined that the total number of lumens that would be installed on the site would be 708,982 and that if the lumens attributable to the lighting that would be on motion sensors and would thus not be operating at most times were taken out of the equation, the total number of lumens would be 356,982.

To establish a frame of reference for evaluating the magnitude of the total number of lumens that would be present on the project site, an analysis was made of the number of lumens created by the outdoor lighting that now exists at the D. Ray James Correctional Facility at Folkston that is a similar distance from the Stephen C. Foster State Park as the proposed mine project (the correctional facility is 23 miles from the park while the closest edge of the proposed mine project's site is 24.7 miles from it). Based on review of Google Earth maps and Street view photos, the number of floodlights on tall masts installed on and surrounding the correctional facility were determined and the type and lumen output of the floodlight fixtures were estimated based on photos and typical lamp/fixtures used for correctional facility applications. Based on this information, the total number of lumens of the lights installed at the correctional facility was determined through the calculations that are documented in Appendix 1. The results of these calculations establish that the floodlights installed at the D. Ray James Correctional Facility have a light output of 5,289,600 lumens, which is over 7 times the number of lumens that will be installed at the proposed mine project. If mine project's lighting on motion sensors, which can be assumed to be turned off at most times, is taken out the mine project's lumen total, the correctional facility's lumen output would be 15 times that of the mine project.

To determine the relative degree of effect that the proposed project would have on the darkness of the skies seen from the state park, calculations were made using an equation developed by astronomer Merle Walker and known as Walker's law. Walker made observations of the light emitted from cities and its effects on night sky viewing conditions at observatories to develop a model that captured the relationship

between sky brightness at observation sites and the population and distance of cities. This model states that the sky glow intensity at the observation site is proportional to the distance from the city raised to the -2.5 power, which reflects a very rapid fall off in sky-glow intensity as the distance increases. The output of Walker's model is the increase in skyglow above the natural background level. Although a strict threshold for how much of an increase in skyglow above the natural background is acceptable, it has been observed that when skyglow is 10% above the natural background levels, it becomes a problem for use of the site for astronomical observations (Walker, 1977 and International Dark-Skies Association, Undated).

In developing his model, Walker found that the total amount of lighting in the cities he evaluated ranged from 500 to 1,000 lumens per capita. To adapt this model for evaluation of the potential skyglow effects of the proposed mine project and for comparative purposes, the correctional facility, the total lumens at each of these sites was translated into equivalent city populations using the both the 500 and 1,000 lumens per capita figures to provide both high and low estimates of the skyglow effects.

The skyglow effect calculations using Walkers Law are documented in Appendix 2. The results indicate that the potential skyglow effects of the total lumens that would be installed at the mine project on the skyglow conditions in the skies seen from the Stephen C. Foster State Park would be very small. Under the most conservative assumptions that take into account the total number of installed lumens, including the 45% of the lumens from lights that are on motion-activated sensors and would be off most of the time, and assume a city population based on 500 lumens per capita, the mine project would increase the level of skyglow above natural conditions by less than two tenths of a percent (0.14%). At the lower end of the range of potential impact, if the lighting that would be on motion-activated sensors were taken out of the equation and a lumens per capita assumption of 1000 were applied, the increase in the level of skyglow above natural conditions would be only four one hundredth of a percent (0.04%).

Walkers Law calculations carried out for the lighting at the C. Ray James Correctional Facility using the 500 and 1000 lumens per capita figures to convert installed lumens to city size determined that the correctional facility's flood lighting increases the level of skyglow in the skies seen from the Stephen C. Foster State Park by .6% to 1.2% above the natural skyglow conditions. The impacts of this facility on skyglow levels at the park are thus 7 to 15 times higher than what the impacts of the proposed mine project would be.

Summary of Walkers Law Calculations

		Increase in sky glow level above the natural background at Stephen C. Foster State Park
Proposed Total installed lumens at the Saunders Demonstration Mine	708,982	0.07% to 0.14%
Proposed Effective total lumens at the Saunders Demonstration Mine accounting for the lights on motion detectors that will not be operating at most times.	356,982	0.04% to 0.07%
Existing total installed lumens of the floodlights in and surrounding the D. Ray James Correctional Facility	5,289,600	0.6% to 1.2%

These calculations thus establish that the lighting proposed at the mine project will have negligible or imperceptible effect on the dark skies conditions at the Stephen C. Foster State Park, and that the project's contribution to the level of skyglow in the skies seen from the park will be very minor in comparison to the impact on those skies now created by the lighting at the D. Ray James Correctional Facility. Because the effects that the project's lighting will have on the nighttime skies condition seen from the park will be so negligible and quite likely undetectable, they pose no threat to park's status as an International Dark Skies Association designated International Dark Sky Park.

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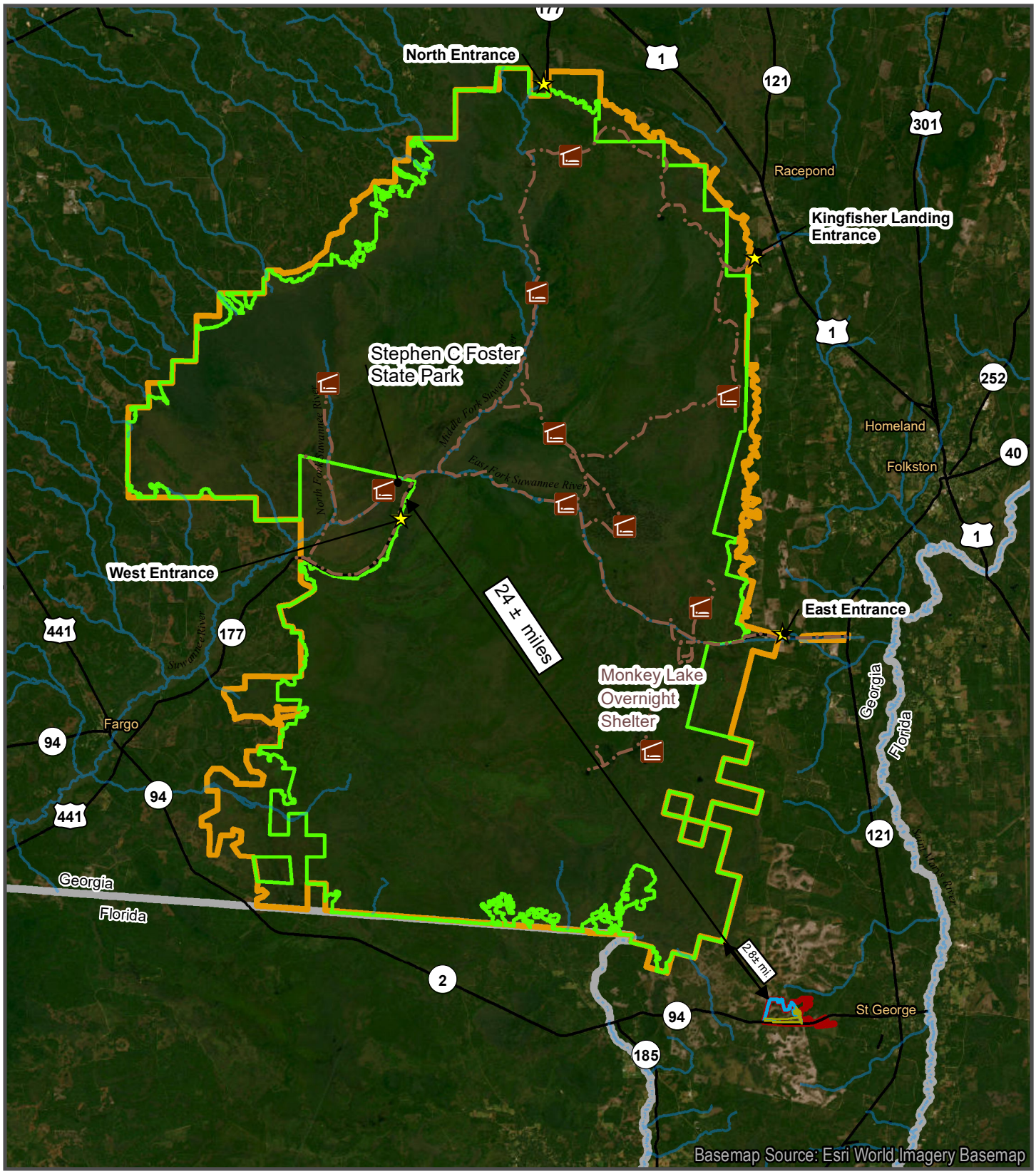
Figures



LEGEND

- Okefenokee NWR
- Okefenokee National Wilderness
- Okefenokee NWR Entrances
- Trails
- Overnight Shelter/Site
- Proposed Mining Area (582 ± AC)
- Project Permit Area (820 ± AC)
- Streams/Rivers
- Major Roads
- State Boundaries

Figure 2. Proposed Saunders Demonstration Mine: Relationship to the Okefenokee National Wildlife Area, Okefenokee Wilderness Area, and Stephen C. Foster State Park
Twin Pines Saunders Demonstration Mine Analysis of Night Lighting

N

0 2 4 Miles

Date created: September 25, 2023

Jacobs

LEGEND

- Okefenokee NWR Entrances
- Okefenokee NWR
- Proposed Mining Area
- Project Permit Area
- Plant Site Plan
- State Boundaries

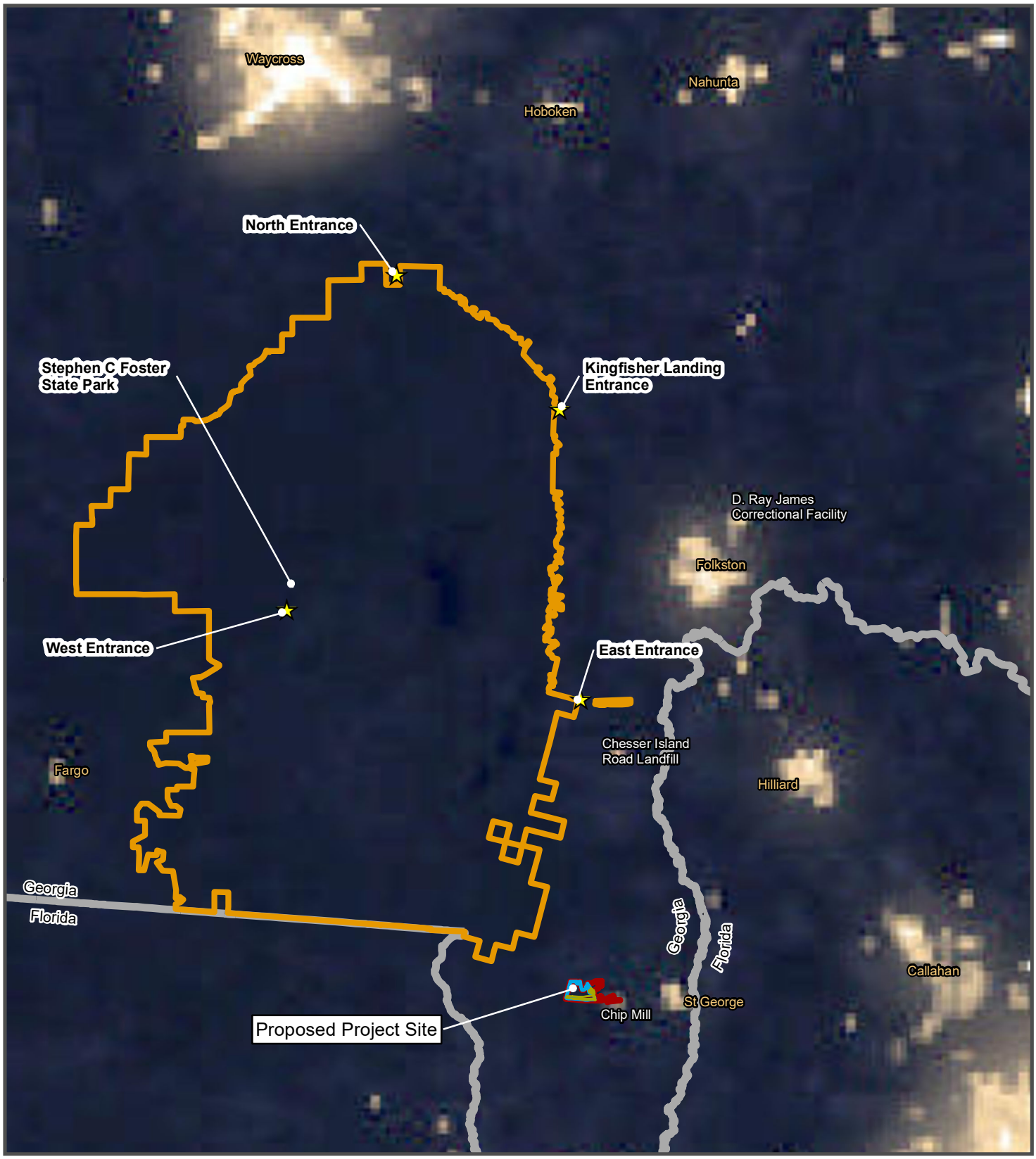
Figure 2. Map of Nighttime Lighting in the Regions Surrounding the Okefenokee Wildlife Refuge and Conservation Area
Twin Pines Saunders Demonstration Mine Analysis of Night Lighting

N

0 10 20 Miles

Date created: September 25, 2023

Jacobs



LEGEND

- Okefenokee NWR Entrances
- Okefenokee NWR
- Proposed Mining Area
- Project Permit Area
- Plant Site Plan
- State Boundaries

Figure 3. Map of Nightime Lighting in the Areas to the East and South of the Okefenokey Wildlife Refuge and Conservation Area
Twin Pines Saunders Demonstration Mine Analysis of Night Lighting

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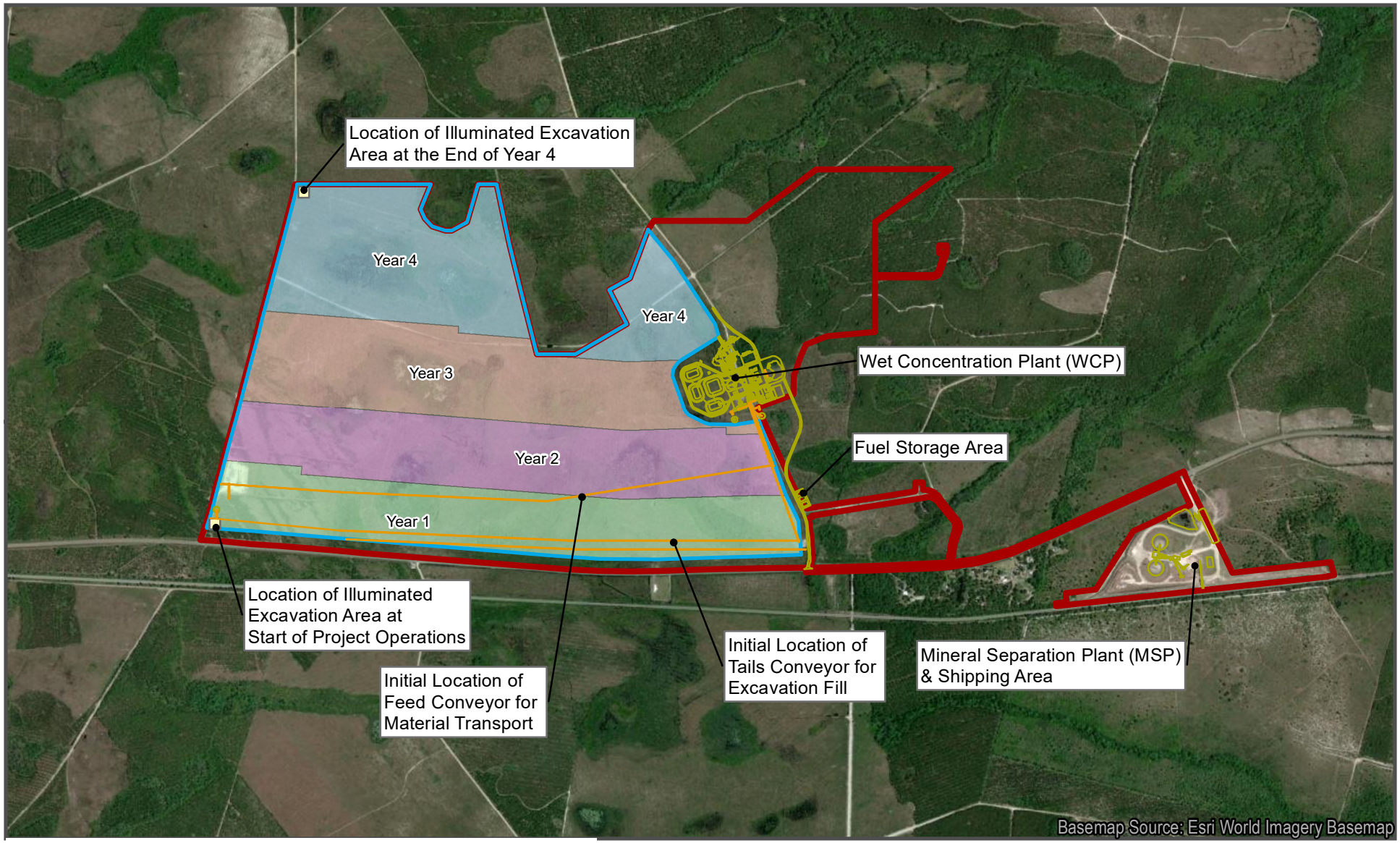
Miles

Date created: September 25, 2023

Jacobs



LEGEND

- Plant Site Plan
- Conveyors for Transport of Feed Material and Tailings
- Proposed Mining Area
- Project Permit Area
- Areas Where Lighting Will be Required for Project Operations

Mining Progression

- Year 1
- Year 2
- Year 3
- Year 4

0 1,000 2,000 Feet

N

Date created: September 25, 2023

Figure 4. Proposed Saunders Demonstration Mine: Locations of Proposed Nighttime Lighting

Twin Pines Saunders Demonstration Mine Analysis of Night Lighting

Jacobs

Appendices

Appendix 1
Saunders Demonstration Mine Analysis of Night Lighting - Lumens Summary

Area	Fixture	Number	Fixture Lumens	Total Fixture Lumens	Effective Lumens	Notes
Dragline	Appleton Area Master	8	25,600	204,800	204,800	
	Appleton Area Mercmaster	2	10,791	21,582	21,942	
Conveyor Belts	LED flood light	40	8,000	320,000	0	Motion activated with sensors -represents 45% of the total lumens installed at the site. At most times will not be in operation, and even then, only a small number of the lights are likely to be on at any one time
Wet Processing Plant	NUVO 9-3/8" w/ LED bulbs	70	400	28,000	28,000	
Fuel Storage Area	LED flood light	4	8,000	32,000	0	motion activated with sensors
Mineral Separation Plant	Appleton Area Master	4	25,600	102,400	102,240	
Total Lumens				708,782	356,982	Total number of lumens installed at the project is 13% of the lumen output of the floodlights at the D. Ray James Correctional Facility. At most times, beause motion activated lights will be off, the effective installed lumens will be slightly under 7% of that of the correctional faclity
D. Ray James Correctional Facility						
Floodlights on Tall Masts Within and Surrounding the Facility	400W metal halide floodlights	174	38,000	6,612,000	5,289,600	Determined based on analysis of Google Earth air photo and Google Earth Street View Photos. Lumen output determined by review of manufacturer cut sheet for this type of floodlight. Because of the design of this fixture, it had to be assumed that the effective lumens are only 80% of the rated lumens

Appendix 2

Walker's Law:

$I = 0.01Pd^{-2.5}$
where I is the increase in sky glow level above the natural background
P is the population of the city
d is the distance to the center of the city in km

Based on his research, Walker determined that the lumens per capita for the cities he evaluated ranged from 500 to 1000

Calculation of the Proposed Project's Potential Skyglow Impacts on Night Sky Conditions in the Stephen C. Foster State Park

Worst case scenario based on an assumption of 500 lumens per capita, which translates to a city population of 1,417.96 and an assumption that all the installed lighting will be turned on

$I = 0.01 \times 1{,}418 \times 39.8^{-2.5}$

$I = 0.01 \times 1{,}418 \times 0.000100006733$

$I = 0.001418$

Under these very worst-case assumptions, the project could result in a 0.14% increase in sky glow level above the natural background at the Stephen C. Foster State Park

Scenario based on an assumption of 500 lumens per capita and the likely condition that the motion operated lights will not be turned on

$I = 0.01 \times 714 \times 39.8^{-2.5}$

$I = 0.01 \times 714 \times 0.000100006733$

$I = 0.000714$

Under these more likely, but still worst-case assumptions which base the population total on 500 lumens per capita, the project could result in a 0.07% increase in sky glow level above the natural background at the Stephen C. Foster State Park

Scenario based on an assumption of 1000 lumens per capita, which translates to a city population of 708 and an assumption that all the installed lighting will be turned on

$I = 0.01 \times 708 \times 36.6^{-2.5}$

$I = 0.01 \times 708 \times 0.000100006733$
$I = 0.000708$

Under this assumption, the project could result in a 0.07% increase in sky glow level above the natural background at the Stephen C. Foster State Park

Scenario based on an assumption of 1000 lumens per capita and the likely condition that the motion operated lights will not be turned on

$I = 0.01 \times 357 \times 36.6^{-2.5}$

$I = 0.01 \times 357 \times 0.000100006733$

$I = 0.000357$

Under assumptions which base the population total on 500 lumens per capita, the project could result in a 0.04% increase in sky glow level above the natural background at the Stephen C. Foster State Park

Walkers Law Analysis of the skyglow effects of the D. Ray James Correctional Facility on darkness conditions at the Stephen C. Foster State Park, using a factor of 500 lumens per capita, which translates to a city population of 13,224

$I = 0.01 \times 13{,}224 \times 37^{-2.5}$

$I = 0.01 \times 708 \times 0.00012008691$

$I = 0.01587$

Assuming a lumens to population factor of 500 lumens per capita, the D. Ray James Correctional Facility is now responsible for producing a 1.6% increase in sky glow level above the natural background at the Stephen C. Foster State Park

Scenario based on an assumption of 1000 lumens per capita and the likely condition that the motion operated lights will not be turned on which translates to a city population of 6,612

$I = 0.01 \times 6{,}612 \times 37^{-2.5}$

$I = 0.01 \times 357 \times 0.00012008691$

$I = 0.0079$

Assuming a lumens to population factor of 1000 lumens per capita, the D. Ray James Correctional Facility is now responsible for producing a 0.8% increase in sky glow level above the natural background at the Stephen C. Foster State Park