REPORT

Lighting Study - Emma Expansion Project Closure/Closeout Plan

Freeport-McMoRan Tyrone, Inc.

Submitted to:

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List of Acronyms and Abbreviations

Baseline	existing conditions
CCP	Closure/Closeout Plan
CDT	Continental Divide Trail
CIE	Commission Internationale de l'Eclairage (International Commission on Illumination)
ELZ	Environmental Lighting Zone
Emma	Emma Expansion Project
EOY	end of year
Golder	Golder Associates Inc.
mag/arcsec^2	magnitudes per square arcsecond
MMD	Mining and Minerals Division
NMAC	New Mexico Administrative Code
NMMA	New Mexico Mining Act
NMWQA	New Mexico Water Quality Act
NMWQCC	New Mexico Water Quality Control Commission
SR 90	New Mexico State Road 90
Tyrone	Freeport-McMoRan Tyrone, Inc.

1.0 INTRODUCTION

Freeport-McMoRan Tyrone, Inc. (Tyrone) is an open pit copper mine located just off State Road 90, approximately 10 miles southwest of Silver City in Grant County, New Mexico (**Figure 1-1**). The proposed Emma Expansion Project (Emma) area is located along the southern boundary of the Tyrone Mine and will include the development of a new open pit and two no-discharging waste rock stockpiles, construction of new haul roads, and installation of various infrastructure to support the project (**Figure 1-2**).

Golder Associates USA Inc. (Golder) was contracted to perform an environmental lighting study in support of the Emma project. The scope of the study includes collecting existing conditions (baseline) lighting measurements, addressing Emma lighting, impact analysis, and addressing mitigation measures if needed. The baseline monitoring study was conducted during a new moon phase on the night of September 7, 2021.

This study is submitted as part of the overall visual resources analysis for Emma, which refers to the natural and cultural landscape features that comprise the landscape surrounding the project as well as their qualities and contribution to landscape character. Natural landscape features include landforms, water features, and vegetation. Cultural landscape features include buildings, roadways, structures, and artificial lighting related to human land uses. The quality of the visual environment has a value to individuals, society, and the economy of a region, particularly in an area where scenic landscapes provide the backdrop for tourism and recreation activities.

This study evaluates whether there is a potential for the lighting characteristics of Emma project components and activities to significantly change the quality of existing setting in the surrounding area.

1.1 Affected Environment

Emma is located in unincorporated Grant County New Mexico, approximately seven miles southwest of Tyrone and five miles north of White Signal. The project is bordered by the Big Burro Mountains to the west and State Road 90 (SR 90) to the east. Closest residences are located approximately one mile south of the Emma site at the Apache Mound subdivision and others east of SR 90. The terrain to the south and east is characterized by flat and gently sloping terrain. The site lies near the foot of the Big Burro Mountains to the west close to the continental divide. Vegetation in the area is dominated by a mixture of grasses, cactus, pinyon pine, and evergreen oaks with one-seed and alligator juniper subdominant, and desert shrub habitats at the project site and to the east and south, with ponderosa pine trees in the Big Burro Mountains to the west.

Land use patterns in the region are primarily rural residential, mining, and large areas of open space. The area to the west of Emma is public land administered by the U.S. Department of Agriculture Forest Service. The region is traversed by paved and unpaved roads and experiences off-road vehicles. Major transportation routes in the region include SR 90, a two-lane highway bordering to the east of the Emma area. No other major roadways are located within 8 miles of the project area. No eligible or designated scenic highways have been identified within the vicinity of the project.

The Continental Divide Trail (CDT) runs through the Gila National Forest approximately five miles to the west of Emma. The CDT is a designated national scenic trail.

The landscape surrounding the Tyrone mine is primarily natural or agricultural land use and therefore has limited sources of artificial light at nighttime. The nighttime viewing conditions are influenced by existing lighting from rural residents, the existing mine, and temporary lighting from vehicle traffic. No street lighting exists along local roadways.

1.2 Project Site

The proposed Emma area will increase the existing mine area by approximately 337 acres. This increase will allow for the construction of the proposed Emma Pit, EMW Waste stockpile, new Southern Haul Roads, and supporting infrastructure. The 6HW Waste stockpile and a new Northern Haul Road will also be constructed as part of this project but will be located entirely within the current approved mine permit area.

Potential areas that can be affected by future nighttime lighting include the residences to the south of Emma starting at the intersection of SR 90 and Tyrone road, and the nighttime recreational uses of Gila National Forest. Project lighting would be used for nighttime mining operations and what is needed for security. Lighting from mining operations would be mobile and/or temporary at locations where mining is occurring at that time or permanent security lighting.

Surface lands in and adjacent to the mine have historically been used for mining, livestock grazing, timber and fuel wood harvesting, recreation, and wildlife habitat. Ponderosa pine was logged in the Big Burro Mountains south of the Tyrone Mine, and fuel wood has been cut from woodlands in this area for at least a century. Recreation in the area includes camping, picnicking, hunting, off-road vehicle use, hiking, horseback riding, and bicycling. Current surrounding land uses include private residences, grazing, mining, and recreation.

1.3 Lighting Basics

Light is part of the electromagnetic spectrum, which ranges from radio waves to gamma rays. Electromagnetic radiation waves are fluctuations of electric and magnetic fields, which can transport energy from one location to another. Visible light is not inherently different from other parts of the electromagnetic spectrum, with the exception that the human eye has evolved to detect visible waves. The human eye responds to light based on its frequency. The frequency of light that is within the visible range establishes the observed color. While the response varies from person to person, the Commission Internationale de l'Eclairage (CIE) defined standard luminosity coefficients for the human eye in 1931.

Light Trespass

Light trespass is defined as the amount of unwanted light from a light source that is transmitted onto adjoining properties. A common light trespass problem occurs when a strong light enters the window of one's home from the outside, causing problems such as sleep deprivation, but light trespass can include any unwanted light that causes a nuisance to the property owner.

Sky Glow

Sky glow is stray light scattering in the atmosphere, brightening the natural sky background level, and reducing star visibility. Sky glow effects are often associated with light pollution that can have a regional effect on perceived lighting conditions. The earliest measures of sky glow, also called sky brightness, were based on a scale upon which the magnitude of stars visible to the human eye is divided into 6 levels. The brightest star is a magnitude 1 and the dimmest (faintest) star is a magnitude 6. More recently, the magnitude scale was modified to express astronomical surface brightness (stars, planets, etc.) in units known as magnitudes per square arcsecond (mag/arcsec^2). The measurement scale is inverse and logarithmic and is generally used in small area photometry and astronomy. Sky Glow classifications and comparisons are presented in **Appendix A**.

2.0 EXISTING SITE CONDITIONS

The assessment of the existing nighttime visual character is based on the current perceived lighting conditions experienced by viewers during the nighttime. To establish a baseline of pre-project lighting conditions, the existing skyglow light levels were measured at selected receptor locations.

Receptor locations were selected to represent a range of sites that experience use during the nighttime and that could potentially be affected by the presence of Project-related exterior lighting including locations related to residences or motorists. The receptor locations are shown in **Figure 2-1**.

Lighting conditions were assessed in terms of percentage brightness above natural dark sky background and were classified based on definitions and descriptions from CIE guidelines, which consist of a set of established Environmental Lighting Zones (ELZ) for classifying exterior light levels (CIE 1997; CIE 2003). These zones and related quantitative thresholds are shown in **Table 2-1**.

Table 2-1: CIE ELZ Classification for Sky Glow

ELZ	Description of the ELZ	Sky Glow (% brightness above natural dark sky)	Sky Glow (mag/arcsec^2)
E1	Intrinsically dark natural (e.g., national parks or protected sites, roads usually unlit)	0 % < x ≤ 20 %	21.3 – 23.0
E2	Areas of low district brightness (e.g., agricultural, industrial, or outer urban / rural residential areas)	20 % < x ≤ 100 %	20.4 – 21.3
E3	Areas of medium district brightness (e.g., industrial, or small-town center's / residential suburbs)	100 % < x ≤ 200 %	18.0 – 20.4
E4	Areas of high district brightness (e.g., town / city centers and commercial areas urban areas, residential and commercial with high levels of nighttime activity)	x > 200 %	<18.0

The assessment of Project related lighting involved a review of available information of the Project lighting layout, luminaires, and illumination levels required for safe operations. This information provided an estimate of the potential incremental increase in lighting that may result from the Project and would influence the current skyglow level. This incremental change combined with measured percentage brightness above natural dark sky background at light receptors was used to determine if anticipated light levels with the Project would exceed thresholds and categories for ELZ. A change in an ELZ class would signal a noticeable change in the perceived lighting conditions experienced by viewers during the nighttime.

A determination of existing light trespass, which is light or illuminance that strays from its intended purpose and potentially becomes an annoyance to nearby receptors, was quantified by comparing the sky glow measured in the 90° angle with that of the horizontal (0°) angle. This serves as an indicator of the light that may be experienced by viewers that could affect perceived lighting conditions at that location.

2.1 Monitoring Results

The nighttime ambient illuminance measurement results from the baseline monitoring study conducted during the night of September 7, 2021 are summarized in **Table 2-2**. The observations were collected during a new moon cycle under clear skies. These conditions were ideal for measuring sky glow with little interference from meteorological conditions that could reflect light back down to the observation point. Measurements were collected at three angles. Sky glow was measured with the meter pointed straight up (vertical) at a 90-degree angle to the ground. Light trespass was measured with the meter pointed at a 0-degree angle (horizontal) towards the proposed Emma site to account for existing light trespass from that location. Lastly a 45-degree angle measurement was captured to measure the transition between sky glow and light trespass.

The nighttime sky glow representing light trespass in the horizontal direction (0°) ranged from 18.7 mags/arcsecond^2 at Site 1 to 22.8 mags/arcsecond^2 at Site 5.

The nighttime sky glow at the transition point (45°) ranged from 20.9 mags/arcsecond^2 at Site 1 to 21.4 mags/arcsecond^2 at Site 5.

The nighttime sky glow in the vertical (90°) direction ranged from 21.3 mags/arcsecond^2 at Site 1 to 21.4 mags/arcsecond^2 at Site 4.

The difference between horizonal (0 degree) measurement and the vertical (90 degree) measurement can be used to represent the amount of light trespass impacting a monitoring site. Existing light trespass was observed at two locations. Site 1 had the most existing light trespass with a difference of 2.6 mags/arcsecond^2, and Site 4 had an existing light trespass of 0.4 mags/arcsecond^2.

Table 2-2: Baseline Lighting Measured for Emma Project, September 2021

Monitoring Location	Sky Glow (mags/arcsecond^2)				Observations
	0	45	90	Difference[a]	
Site 1	18.7	20.9	21.3	2.6	Clear sky. Residential security light behind meter. Light on equipment for Tyrone Mine Operations in view of meter while pointed toward Emma site.
Site 2	21.4	21.1	21.3	0.0	Clear sky. Distant glow from mine ops and of Tyrone/Silver City observed.
Site 3	21.7	21.0	21.4	0.0	Clear sky.
Site 4	21.1	21.1	21.4	0.4	Clear sky. Residential light in view, Distant glow of mine ops and city of Tyrone/Silver City observed.
Site 5	22.8	21.4	21.4	0.0	Clear sky. No lights visible.

Note: [a] If negative the result was zeroed.

2.2 Monitoring Discussion

Monitoring results summarized in **Table 2-2** indicate that the project area can be categorized as an E1 environmental zone with little existing light trespass. The major lighting source in the area is the existing operations of the Tyrone Mine, which is the main source of light trespass at Site 1, but even with that source located directly across the road from Site 1, it was still considered an E1 zone. Light trespass at Site 4 indicates there are some existing residential light sources with minor affects to neighboring receptors.

3.0 PROJECT IMPACTS

The proposed Emma Pit is anticipated to encompass approximately 116.3 acres of private land at the EOY 2026 (**Figure 3-1**). The changes to light sources during project operations will include new lighting of Project facilities to illuminate work areas for safety and security purposes. This will include a combination of mobile lighting, pole mounted lighting, and wall mounted fixture on buildings, as well as the application of best practices to minimize the effects of obtrusive exterior lighting (e.g., shielding light fixtures directed downward, scheduling controls).

Using Site 1 and Site 3 as a gauge of the sky glow impact the current operations have on the surrounding area, the Emma project will have little to no impact on sky glow at any of the neighboring receptors. The CIE ELZ for all light receptors is predicted to remain within the ELZ E1 classification zone. As such, lighting from Emma during operations will be a minor contributor to light levels and is not anticipated to change the overall existing light environment during night-time viewing.

Given that the closest residential receptor will be approximately a mile away from Emma, no light trespass is anticipated at that distance. During initial phases of the project, while at ground level, lighting will be visible at receptors to the south of the project. This will be temporary (less than one year) as berms, stockpiles, and the pit are constructed. Once constructed, most of the lighting is anticipated to be indirect to these off-site receptors and not perceptively different from the existing Tyrone Mine operations.

Overall, it is anticipated that new visual light sources will be evident to nearby viewers but would not increase the overall perceived light levels, maintaining current nighttime viewing conditions anticipated for a rural setting. While lighting required during Project operations would create new sources of light, Project effects from light and glare on day or nighttime views would be less than significant.

4.0 MITIGATION

As no significant adverse impacts to visual resources were identified, no mitigation measures are deemed necessary. This assumes the use of best lighting practices as implemented for the Tyrone Mine.

5.0 REFERENCES

Commission Internationale de l'Eclairage (CIE). 1997. Technical Report: Guidelines for Minimizing Sky Glow. Vienna, Austria: Commission Internationale de l'Eclairage Report No.: CIE 126: 1997, ISBN 978 3 900734 83 1.

CIE. 2003. Technical Report: Guide on the Limitation of the Effects of Obtrusive Light from Outdoor Installations. Vienna, Austria: Commission Internationale de l'Eclairage Report No.: CIE 150: 2003, ISBN 9788 3 901906 19 0.

Signature Page

Please contact the undersigned with any questions or comments on the information contained in this report.

Respectfully submitted,

Golder Associates USA Inc.

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https://golderassociates.sharepoint.com/sites/149301/project files/6 deliverables/006-lighting study/rev0/21476949-005-r-rev0-emma_lighting_study-03nov21.docx

Figures

STATE OF NEW MEXICO

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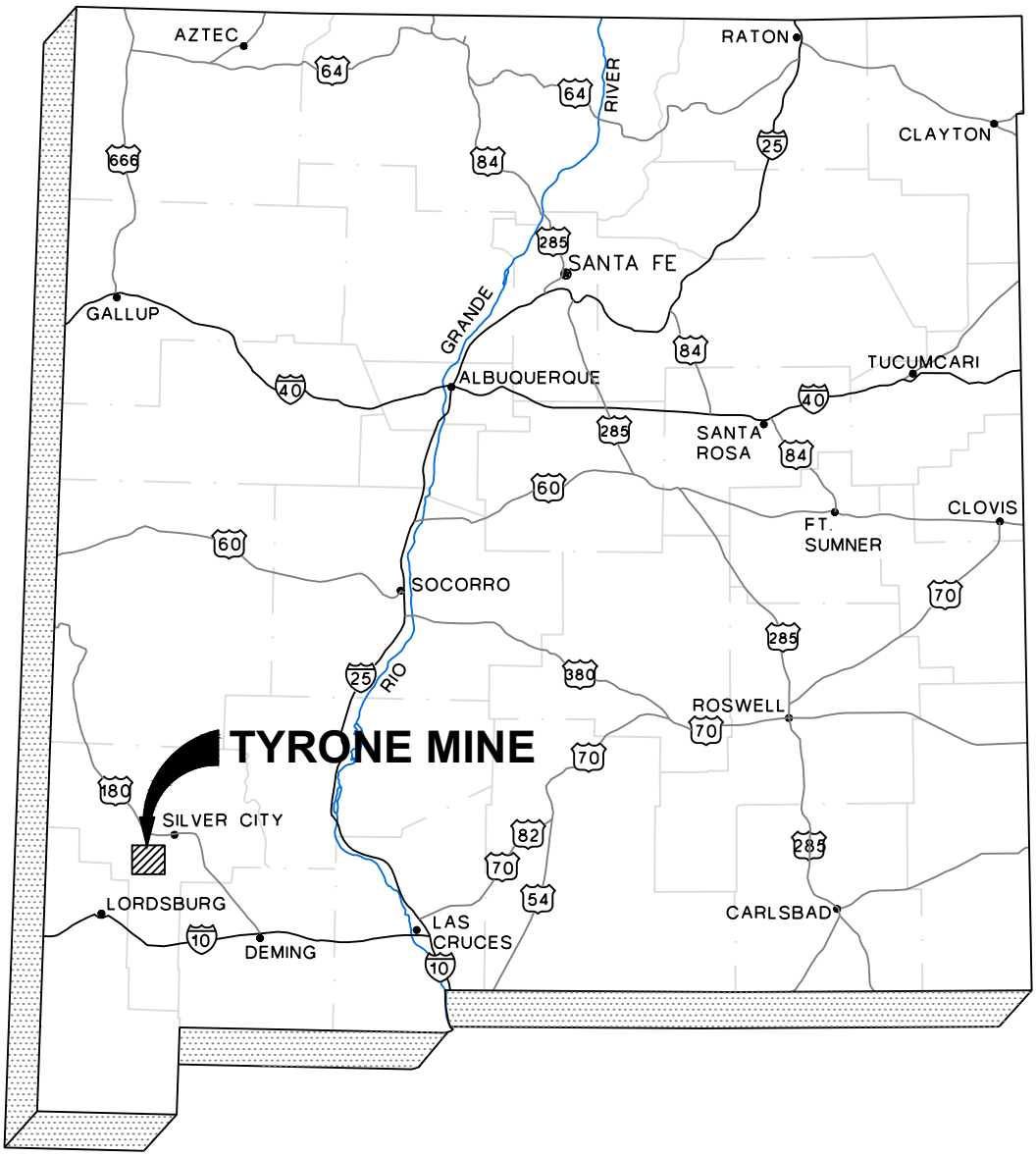

CLIENT
FREEPORT-MCMORAN TYRONE INC.

PROJECT
EMMA EXPANSION PROJECT CCP

CONSULTANT
GOLDER
MEMBER OF WSP

YYYY-MM-DD	09/17/21
PREPARED	SIB
DESIGN	TS
REVIEW	TS
APPROVED	TS

TITLE
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PROJECT No.	PHASE	Rev.	FIGURE
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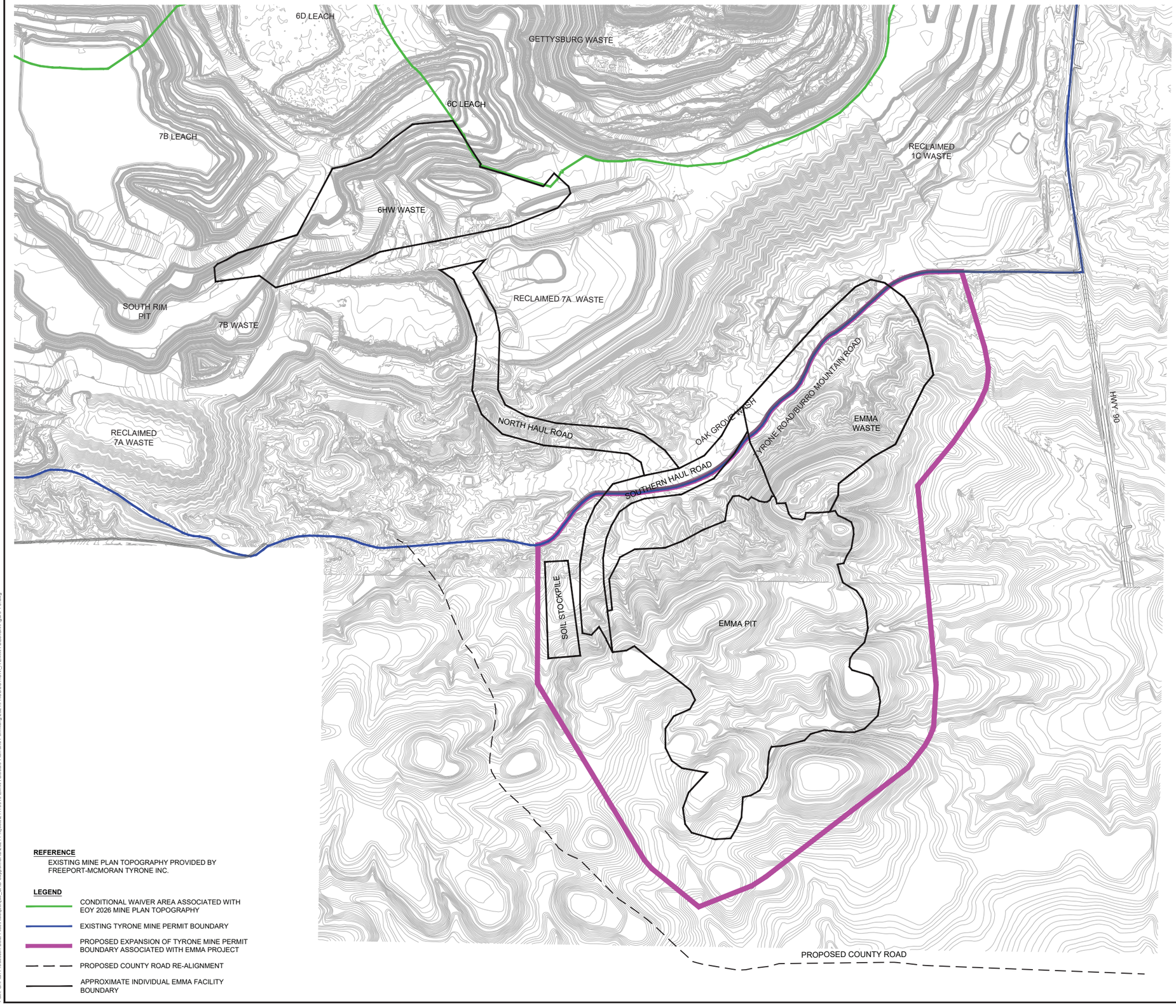

REFERENCE

EXISTING MINE PLAN TOPOGRAPHY PROVIDED BY FREEPORT-MCMORAN TYRONE INC.

LEGEND

- CONDITIONAL WAIVER AREA ASSOCIATED WITH EOY 2026 MINE PLAN TOPOGRAPHY
- EXISTING TYRONE MINE PERMIT BOUNDARY
- PROPOSED EXPANSION OF TYRONE MINE PERMIT BOUNDARY ASSOCIATED WITH EMMA PROJECT
- PROPOSED COUNTY ROAD RE-ALIGNMENT
- APPROXIMATE INDIVIDUAL EMMA FACILITY BOUNDARY

SCALE 150 0 150 300 FEET

REV.	MM/DD/YY	DESCRIPTION	DESIGN	CADD	CHECK	REVIEW
0	2021-09-10	-		SIB		

SEAL

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PROJECT
EMMA EXPANSION PROJECT CCP

TITLE
PROPOSED EXPANSION OF EXISTING TYRONE MINE PERMIT BOUNDARY & MINING AREA DESIGN LIMIT FOR EMMA

PROJECT NO.
21-476949

REV. 0 of FIGURE 1-2

0 1 in IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM ARCH D

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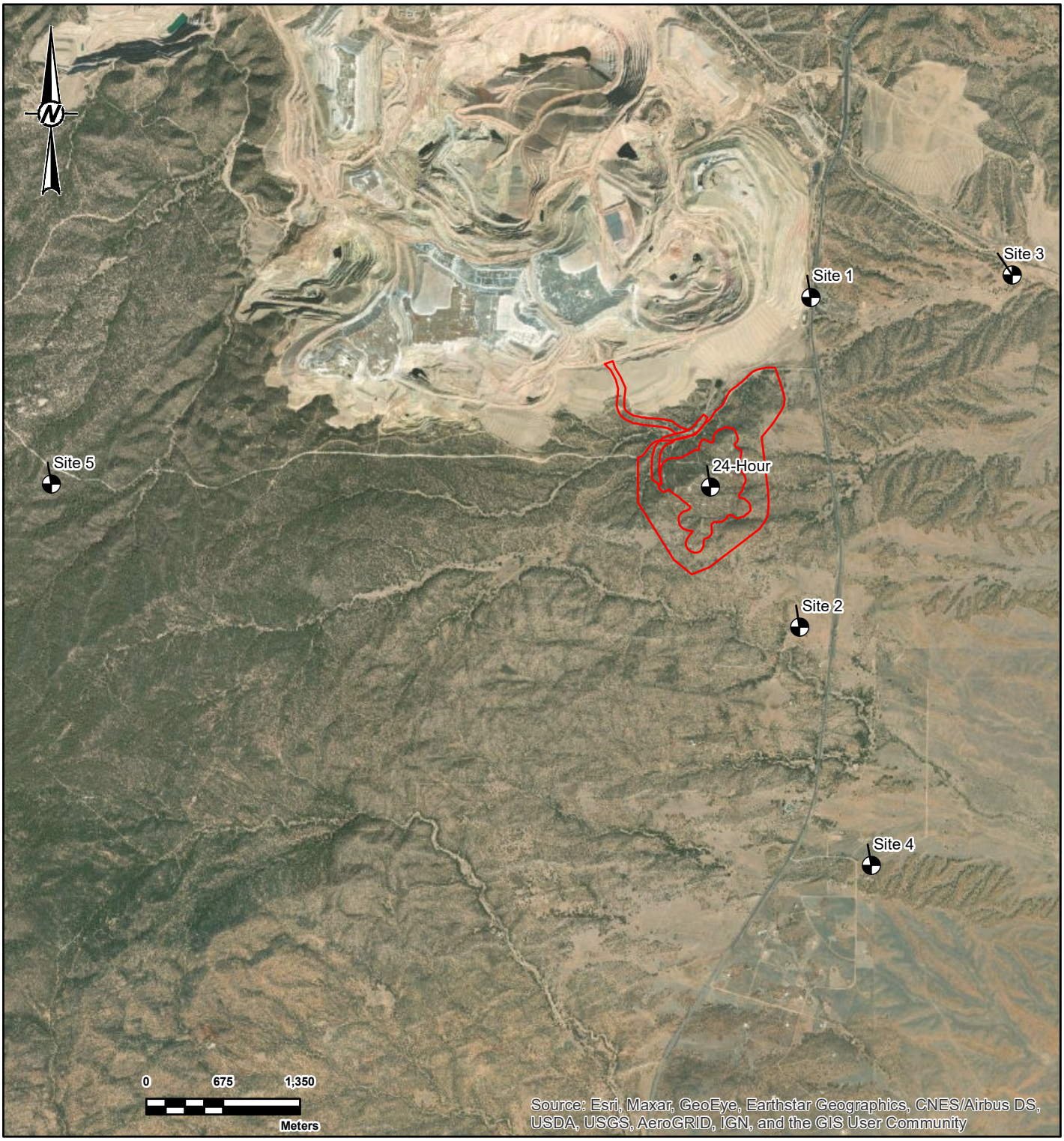

LEGEND

- Sky Glow Monitoring Locations
- Emma Site Layout

REFERENCE(S)
1. NOISE MONITORING LOCATIONS, GOLDER ASSOCIATES INC., 2021.
2. SITE LAYOUT, FREEPORT-MCMORAN TYRONE INC. 2021

COORDINATE SYSTEM: NAD 1983 STATEPLANE NEW M
PROJECTION: TRANSVERSE MERCATOR
DATUM: NORTH AMERICAN 1983
UNITS: FOOT US

CLIENT
FREEPORT-MCMORAN TYRONE INC.

PROJECT
EMMA EXPANSION PROJECT

TITLE
SKY GLOW MONITORING LOCATIONS

CONSULTANT
GOLDER

YYYY-MM-DD	2021-07-29
DESIGNED	GFD
PREPARED	JGW
REVIEWED	
APPROVED	

PROJECT NO.	CONTROL	REV.	FIGURE
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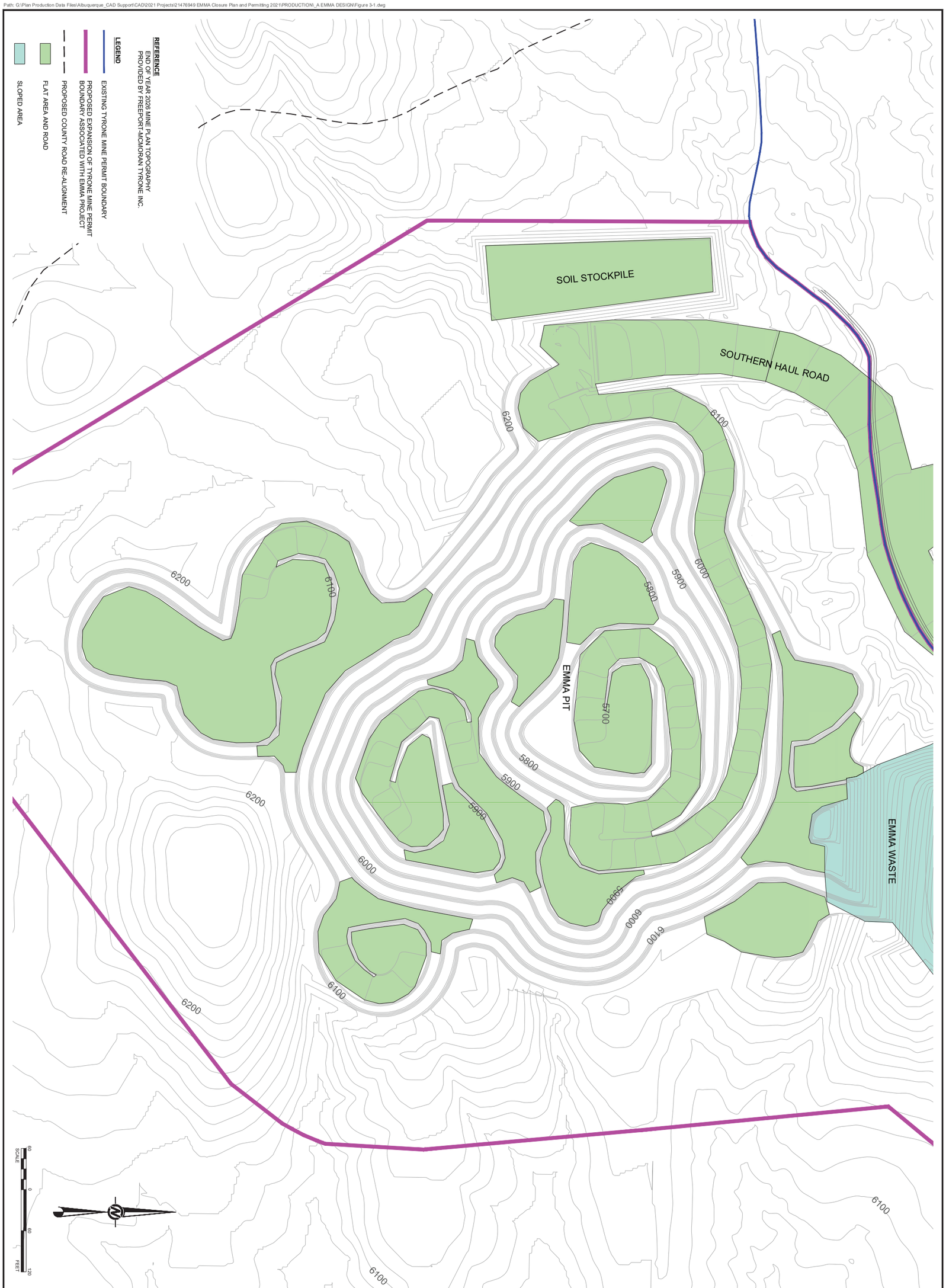

PROJECT
EMMA EXPANSION PROJECT CCP

CLIENT
FREEPORT-MCMORAN TYRONE INC.

SEAL

TITLE
OPERATIONAL EMMA PIT CONFIGURATION AT THE END OF YEAR 2026

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PROJECT NO.
21-476949

REV. 0

FIGURE 3-1

REV.	MM/DD/YY	DESCRIPTION	DESIGN	CADD	CHECK	REVIEW
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APPENDIX A

Sky Glow Comparison Tables

Sky Glow Comparison Table

Class	Title	Approx. SQM mag/arcsec²
1	Excellent dark-sky site	21.7–22.0
2	Typical truly dark site	21.5–21.7
3	Rural sky	21.3–21.5
4	Rural/suburban transition	20.4–21.3
5	Suburban sky	19.1–20.4
6	Bright suburban sky	18.0–19.1
7	Suburban/urban transition	
8	City sky	< 18.0
9	Inner-city Sky	

Source: Bortle, John E. (February 2001). "Gauging Light Pollution: The Bortle Dark-Sky Scale". Sky & Telescope. Sky Publishing Corporation. Retrieved 2020-05-29.

Examples of Typical Illuminance and Apparent Magnitude

Location	Classification	Illuminance [a] (lux)	Sky Brightness[b] (mag/arcsec²)
Outdoor	Bright Sun	100,000 - 130,000	>0.1
	Hazy Day	32,000	1.3
	Partly Cloudy	25,000	1.6
	Cloudy	10,000	2.6
	Overcast	1,000	5.1
	Sunrise/Sunset on Clear Day	400	6.1
	Full Moon	0.1	15.1
	Moonless Clear Night Sky	0.001	20.1
	Moonless Overcast Night Sky	0.0001	22.6
	Starlight	0.00005	23.3
Indoor	Typical TV Studio	1,000	5.1
	Bright Office with Large Contrast	400	6.1
	Hall Way	80	7.8
	Living Room	50	8.3
	Good Street Lighting	20	9.3
	Poor Street Lighting	1	12.6

Notes: a) Electro-Optics Handbook,1979; Williams, 1999; b) Calculated based on conversion from lux to mags/arcsecond²

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