New Mexico Energy, Minerals and Natural Resources Department
Abandoned Mine Land Program
1220 South Francis Drive
Santa Fe, NM 87505

Navajo North Site Assessment and Recommendations Report

McKinley County, New Mexico

AML Project SHARE No. 19-521-0620-0191 Task Order 7

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McKinley County, New Mexico

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PRESENTED TO

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The contents of this report do not necessarily represent the views or policies of the State of New Mexico, Energy, Minerals and Natural Resources Department, Abandoned Mine Lands Program or United States Department of the Interior, Office of Surface Mining Reclamation and Enforcement. Subsurface conditions may vary from those depicted in this report. No warranty of geologic conditions is expressed or implied.

The site conditions and resulting recommendations presented in this document are based on conditions encountered at the location at the time they were conducted. Due to the dynamic nature of abandoned mine land sites, the complexity and variability of natural earth and rock formations and materials, significant variations may occur between and around these locations or with time. Because these data represent a very small statistical sampling of overall site conditions, it is possible that conditions may be encountered that are substantially different from those indicated. In these instances, modification and adjustment to the recommendations presented may be warranted.

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ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
ags	above ground surface
AML	Abandoned Mine Land Program
amsl	above mean sea level
bgs	below ground surface
cfm	cubic feet per minute
FAA	Federal Aviation Administration
ft	feet
GPS	Global Positioning System
PPE	Personal Protective Equipment
SOW	Scope of Work
UAS	Unmanned Aerial System (Drone)
°	Degrees
°F	Degrees Fahrenheit

1.0 INTRODUCTION

The work completed on the Navajo North Site Assessment project was authorized by the State of New Mexico, Energy, Minerals and Natural Resources Department, Abandoned Mine Lands Program (AML) as part of services contracted for AML Project SHARE No. 19-521-0620-0191 Task Order 7 – Navajo North Engineering Site Assessment, Gallup, New Mexico per the notice-to-proceed letter dated April 22, 2021. The start of the project was delayed until cooler weather conditions (Fall) were present to maximize thermal imagery effectiveness. This report presents the findings for the Navajo North site assessment which was completed November 3 and 4, 2021.

The Navajo North assessment area (Navajo North) is located on land owned by Gallup Land Partners, LLC and is three miles north of downtown Gallup, New Mexico. The area is located east of the Navajo Number 5 coal mine and above the Gallup-Gibson coal mine (**Figure 1**).

1.1 Purpose

The purpose of this report is to present the findings of Tetra Tech's records review and site assessment of the Navajo North area and to evaluate options for management and/or mitigation.

1.2 Scope of Work

The scope of work (SOW) included a mine map review prior to mobilization, an initial site visit, and recommendation of mitigation options. The literature review included researching the Gallup Coalfield's history, local and regional geological maps, and information provided by the State of New Mexico. The initial site investigation included mapping of site surface features, inventory of surface feature temperatures with infrared thermometers and cameras, and emissions analysis of feature atmosphere. An Unmanned Aerial Systems (UAS) survey was performed using thermal and visual sensors.

Prior to mobilization a project specific health and safety plan was developed for anticipated site activities. Personal Protective Equipment (PPE) required for work on this project near coal mine fires included a personal gas monitor, infrared thermometer, sturdy boots, long pants, and task appropriate work gloves. Vents were approached from the upwind side, and personal gas monitors were worn near the breathing zone. An infrared thermometer was used to determine ground temperatures before approaching areas near vents or other surface expressions of the fires.

2.0 RECORDS REVIEW

A review and correction of mine maps was performed using Geographic Information Systems (GIS) to identify if any known mines are located in the immediate area of the Navajo North. A literature search was performed at the local public library and Rex Museum in Gallup, NM, and on the internet, and reports from researchers and AML personnel were reviewed to better understand the history and progression of the mine fire.

Information about the Gallup-Gibson mine was found in the 1988 Howard B. Nickelson report titled "*One Hundred Years of Coal Mining in the San Juan Basin, New Mexico"*. This report provided information on the mine location, production, and history.

2.1 Site Description and Geology

The Navajo North area is located on land owned by Gallup Land Partners, LLC and is three miles north of downtown Gallup. The site is accessed from a locked Gallup Land Partners gate at the north end of the Gallup Flea Market. Navajo North area can be accessed by vehicle. The parking location for the area is another 2.1 miles north then east on an unimproved dirt road. All features lie within a 350-foot radius of parking area on the powerline road besides the O'Malley feature which is a ¼ mile hike from its respectively parking area. The site is at approximately 6,800 feet above mean sea level (ft amsl). Vegetation consists of a mix of sage brush, rabbit brush, greasewood, western rag weed and cheat grass. Annual precipitation averages 11 inches per year (WRCC, 2019).

The mined interval is located in the Cretaceous Gallup-Zuni sub-basin on the southern end of the greater San Juan Basin northwest of the Zuni Mountains and south of the Chaco Slope. Mines in the area lie within the Gibson coal member of the Crevasse Canyon formation. The Gibson coal member consists of multiple coal beds from 2.5 to 6 ft thick (Sears, 1925). **Figure 2** shows the geologic setting of the site.

2.2 Mining History and Legacy

The Navajo North area features appear to be associated with the Gallup-Gibson Mine. The entrance to this mine is located 2,000 feet southeast of the Navajo North area with the main slope descending 5,000 feet at an approximate bearing of N30˚W. Coal beds within the Gallup-Gibson mine dip 5° at the entrance (southeast corner of the mine) and 22° at the end of the main slope (northwest corner of the mine). The Gallup-Gibson Mine operated from 1881 until 1904 producing between 21,000 and 180,000 tons annually. In 1891, a fire in the No. 4 seam was started by spontaneous combustion and sealed off from the rest of the mine. In 1901, carbon dioxide was found coming through the brick wall that sealed off the No. 4 seam fire. This fire would ultimately close the mine in 1904. In 1905, a triple stone barrier was installed to protect the remaining coal, which was later accessed from the east through the Weaver mine, and the Gallup-Gibson mine entrances were sealed (Nickelson, 1988).

Currently there is an underground fire believed to be associated with the former Navajo Mine located approximately 1,500 feet to the south, near the former locations of the Navajo and Gibson Mine adits. For more information on this fire, please see Tetra Tech's inventory report (AML Project SHARE No. 19-521-0620-0191 Task Order 3) dated April 24, 2020.

2.3 Mine Maps

The Navajo No. 5 mine map (1924), Navajo No. 3, 3.5. and 5 map (1944) and Gallup-Gibson mine map (assumed 1904) were reviewed during this investigation. The georeferencing of these maps was corrected based on surface

features and the corrected geotiffs are supplied with this report. The locations of the surface features over the mine maps for the area are shown on **Figure 3**.

3.0 FIELD INVESTIGATION

The Navajo North area was visited November 3, 2021 and November 4, 2021 by Tetra Tech staff. Weather conditions were clear and 60˚ with overnight temperatures in the high 20s. The site assessment included on-ground inspection of site features, temperature measurements, UAS photogrammetry and thermal imaging flights, and emission analysis.

Procedures and observations from these tasks are discussed in the sections below. Site photographs are included in **Appendix A**. Project ArcGIS data will be transmitted to AML electronically.

3.1 UAS Survey

A UAS visual inspection flight was performed in the afternoon of November 3, 2021 and a pre-dawn thermal inspection and photogrammetry flight was performed on November 4, 2021. A thermal photogrammetry flight was also performed to map heat in the Navajo North area. This flight produced high-resolution visual and thermal orthomosaic imagery. **Figure 4** shows the areawide thermal image with some key locations highlighted. As can be seen in the thermal imagery, it is hard to distinguish the subsidence features from other relatively warm objects like rock outcrops and trees that are still emitting small amounts of heat from the previous day's solar heating. This is because the temperature of the venting mine atmosphere is relatively low and close to the background temperatures.

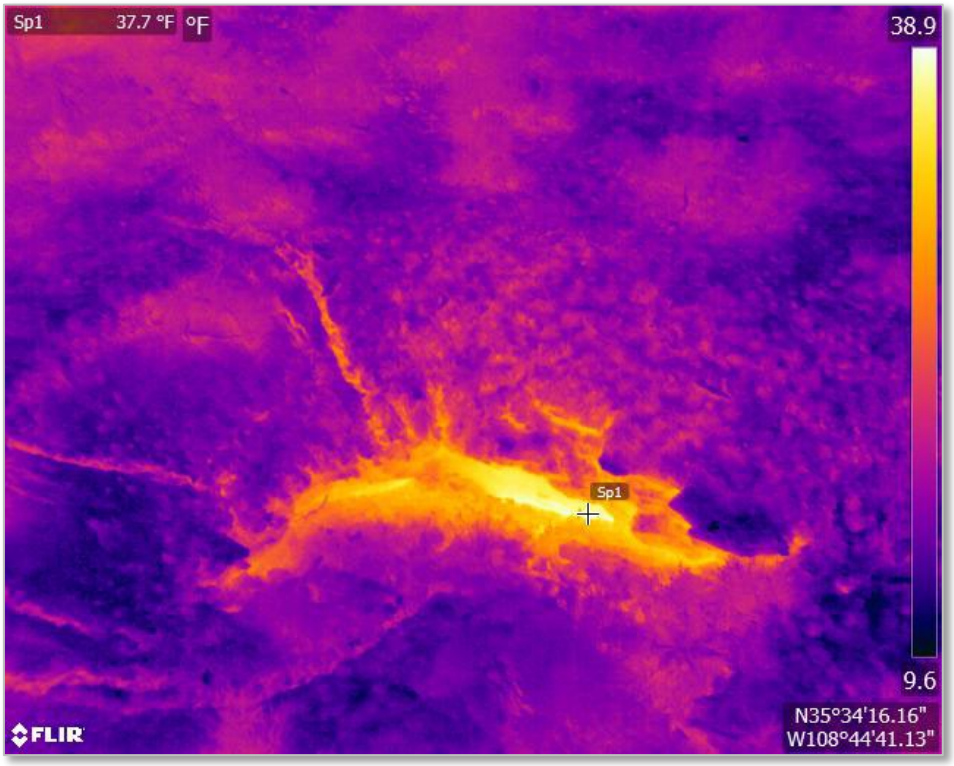


Image 1: UAS-Thermal Image of Navajo North Subsidence Feature SF3.

Additionally, a 1.5 square mile area surrounding the Navajo North area was flown at a high level searching for thermal anomalies that would indicate mine, refuse pile, or outcrop fires. No thermal anomalies were identified besides the Navajo North subsidence features and the Navajo Fire. This data is provided electronically.

3.2 Feature Mapping

The Navajo North area was visited on November 3 and 4, 2021, and site features were inventoried with gas analysis and temperatures recorded. **Figure 2** shows the feature locations and photos are included in **Appendix A**. The five features identified in the request for proposal were located, examined, and assigned a unique ID. Several possible subsidence features (SF) were also identified. Characteristics of each of the site features are described below and photographs referenced are included in **Appendix A**.

1. **SF1** (Navajo North Decline 1) A sinkhole subsidence feature, approximately 15 feet in diameter with a fracture in the bedrock at the base surrounded by green moss (Photo 1). There's a steady flow of musty air venting from the fracture. Temperatures in the subsidence features were found to be between 40˚ F and 50˚ F. No hazardous gases or combustion indicators detected.

2. **SF2** (Navajo North Decline 2) A discrete fracture in the bedrock wall of a small sinkhole (Photos 2 and 3). Appears quite deep with a musty odor and slight flow of air. Temperatures were close to ambient and no hazardous gases or combustion indicators were detected.

3. **SF3** (Navajo North Decline 3) This sinkhole subsidence feature is approximately 30 feet in diameter with an opening in the fractured sandstone at the base of the southern wall (Photo 4). Image 1, above is the thermal image of the opening showing a high temp of 37˚ F with background temperatures in the 20's˚ F.

4. **SF4** This subsidence feature previously identified as Navajo North Vent 2 is shown in Photo 5.

5. **SF5** (Navajo North Vent 1) Photo 6 shows the measurement of gas concentrations from the low flow from this small subsidence feature. Temperatures were slightly above ambient, and no hazardous gases or combustion indicators were observed.

6. **SF6** One additional 8-inch diameter subsidence feature (Photo 7) was located near the wash 200 feet to the northeast of the previously identified features. This feature's temperature was 46ºF. No odors or gases were observed or detected.

7. **SF7** Photo 8 shows a broader depression south of the overhead powerline maintenance road that is possibly related to mine subsidence. It is approximately 30 feet in diameter and there are no open fractures, recent signs of movement, or venting.

8. **SF8** This is a broad, shallow depression that is very similar in size to SF3 and possibly the initial expression of a subsidence feature.

The O'Malley feature was visited and inspected in the afternoon of November 3, 2021. No thermal anomalies, odors, or gases were observed or detected, and the evidence suggests that it is a natural erosional feature. Photos 10, 11, and 12 in **Appendix A** show the highly erodible layer beneath a more competent sandstone layer. Natural contours funnel water through fractures in the overlying sandstone above and behind the main feature. With water entering the formation behind the face of the cliff, the resulting erosion has formed a cave like feature.

Similar, yet smaller erosional features are present in the immediate vicinity and in the same geologic layer around this butte. None of the features showed elevated temperatures or other indications that would suggest the features are associated with historic mining activities and all appeared to be natural erosion.

3.3 Emissions Analysis

Emissions from the Navajo North subsidence features were analyzed using a Landtec GEM 5000 gas analyzer. The gases measured by the GEM 5000 are listed in **Table 1** and the gas levels are listed in **Table 2**.

Table 1. Landtec GEM 500 Gas Analyzer

Equipment	Gases Analyzed				
GEM 5000	Methane (%)	Carbon Dioxide (%)	Oxygen (%)	H2S (ppm)	Carbon Monoxide (ppm)

A representative emissions analysis of the Navajo North features was performed by inserting the collection tube into the feature as far as possible. Due to the low flowrate of gases from the features and dilution from ambient atmosphere, the resulting gas concentrations may be lower than the actual mine atmosphere concentrations.

Table 2. Vent Emission Summary

Gas	SF4	SF5	SF2	SF1	OSHA/NIOSH Exposure Limits
Methane - CH_4	0.0%	0.0%	0.0%	0.0%	0.1%
Carbon Dioxide - CO_2	0.1%	0.2%	0.7%	0.4%	0.5%
Oxygen - O_2	18.9%	18.6%	18.3%	18.6%	19.5% minimum
Hydrogen Sulfide - H_2S	0 ppm	0 ppm	0 ppm	0 ppm	20 ppm
Carbon Monoxide - CO	0 ppm	0 ppm	0 ppm	0 ppm	200 ppm

As shown in **Table 2**, slightly increased carbon dioxide readings and decreased oxygen readings were recorded indicating typically closed (non-vented) coal mine atmosphere where low temperature coal oxidation has reduced oxygen levels while resulting in increased carbon dioxide levels. Carbon monoxide and high levels of carbon dioxide, which are typical of high temperature coal oxidation and fire were not detected. These conditions are typically seen in mines that are not experiencing high temperature coal oxidation and/or fire.

4.0 FINDINGS AND RECOMMENDATIONS FOR FUTURE WORK

4.1 Findings

The Navajo North features do not appear to be venting mine fire exhaust. Gas concentration, temperature analysis, and observed air moisture indicate that the features are venting mine atmosphere from a considerable volume of mine workings. Review of mine maps for the Gallup-Gibson mine show workings in the shallowest mined coal seam (No. 3 seam) beneath the Navajo North features. The mine map shows no adits or shafts located in the immediate vicinity of the features and there is no evidence on the surface that there was an entrance in the area. It is believed that the Navajo North features are subsidence features related to the roof collapse in a room or haulage and not related to a shaft or adit.

The sections below describe options to manage/mitigate this exposure risk.

4.2 Fire Management and Abatement Options

4.2.1 Option 1: No Action with Biennial Monitoring

Cost Estimate: <$1,000/year

The No Action option would leave the site as it is. Risks associated with this option are the low risk that the current mine atmosphere venting activity will propagate coal oxidation into a mine fire and the low risk of trespassers to be injured or killed by subsidence and/or gases from the vents.

4.2.2 Option 2: Backfilling Subsidence Features w/ Biennial Monitoring (Recommended Option)

Cost Estimate: <$15,000 initial cost and $1,000/year for monitoring.

This option would involve backfilling the open subsidence features to mitigate the low potential fall hazard as well as help reduce the amount of air flow through the old mine workings to slow oxidation within the mine. **Figure 5** shows the disturbance extents for each backfill area.

To avoid disturbance of extensive cultural resources in the Navajo North area, polyurethane foam (PUF) may be used as a backfill material. The PUF can be transported by hand or wheelbarrow along a path designated by AML to avoid disturbance to the area. A soil cover of no less than two feet thick will be placed over the PUF plug. Soil may be obtained from the area immediately surrounding the subsidence feature if the area has been designated as clear of cultural resources by AML or a qualified archaeologist monitoring the work. Any additional soil necessary for cover purposes may be imported as needed from the excavated soils obtained during extinguishment of the Navajo No. 1 Fire area and will be staged in discreet piles along the main access road to the Navajo North area.

4.2.3 Option 3: Drilling Investigation

Cost Estimate: $25,000-$100,000 for geophysical/drilling investigation

This option would be a phased approach beginning with a drilling and/or geophysical investigation to fully delineate the extents of the mine workings in the area and provide basis for potential abatement design. The initial investigation would likely consist of a combination of geophysical and drilling activities to evaluate geotechnical properties of the overburden material, thickness of the overburden, and full extents of the underground coal mine workings.

5.0 REFERENCES

Gallup American Coal Co., September 1, 1924, 5th Vein Navajo Mine and No. 5 Mine, Scale 1"=200', Map No. 1497, Unknown Publisher.

Koveva, Inc. 2014-2015, Phases 1, 2, & 3 Navajo No. 1 Coal Mine Fire Reports.

McDonald, Meghan J. 2019. Navajo #1 Mine Fire Site Visit Report, May 28-29, 2019, New Mexico Abandon Mine Lands Program, May 31, 2019.

Nickelson, H. B., 1988, One Hundred Years of Coal Mining in the San Juan Basin, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin 111.

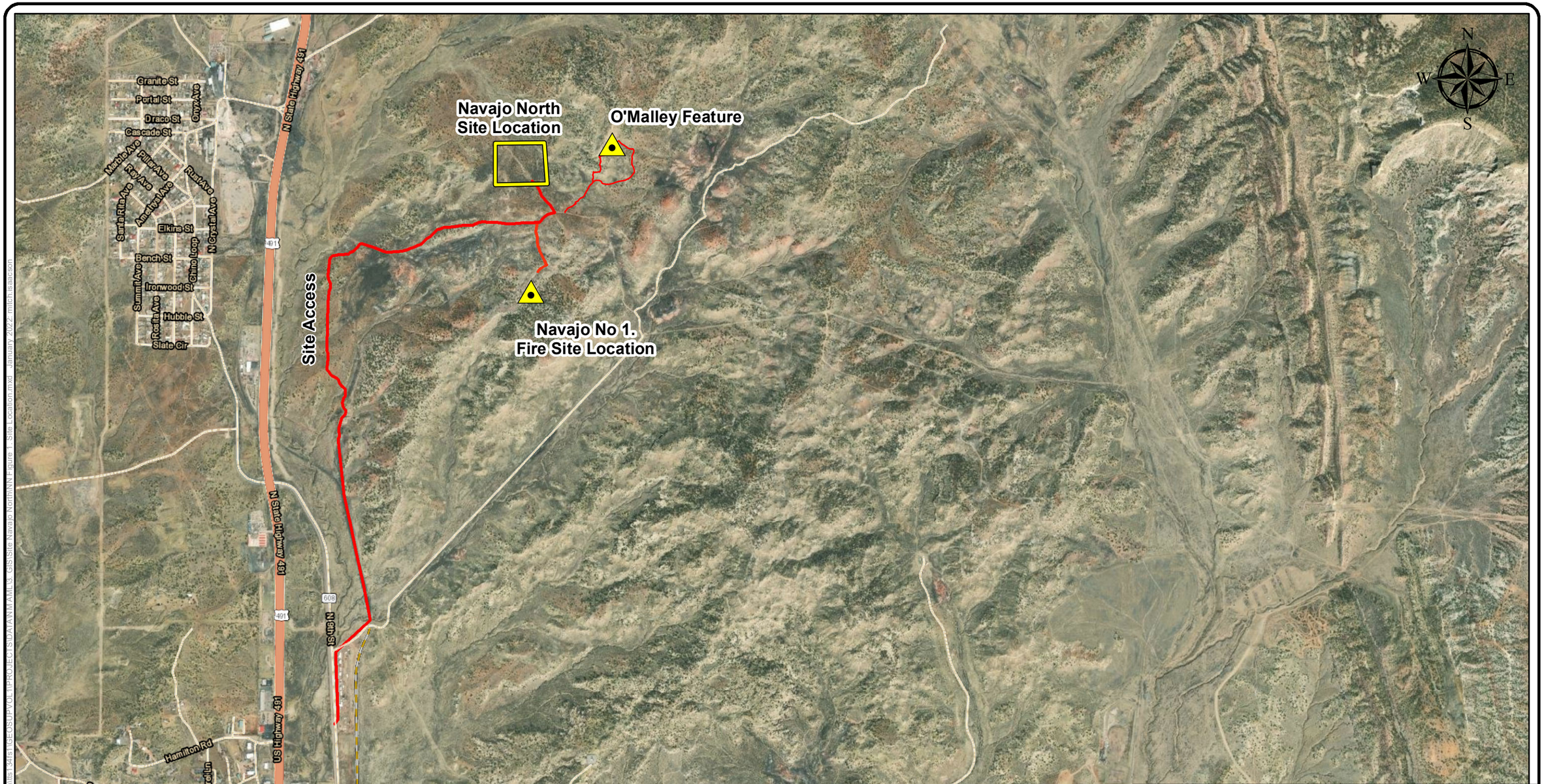
Sears, J. D, 1925, Geology and Coal Deposits of the Gallup-Zuni Coal Field, New Mexico, Colorado: U. S. Geological Survey Bulletin 767.

Tetra Tech, 2011, Gallup Coal Inventory Project: Abandoned Mine Feature Inventory. Tetra Tech Inc, January 4, 2011.

USGS, 1990, Geologic map and structure contour maps of the Gallup 30' X 60' quadrangle, McKinley County, New Mexico (NGMDB), U.S. Geological Survey.

Western Regional Climate Center (WRCC), Climate Summary for Gallup, N.M. https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?nm3422, accessed December 31. 2019.

FIGURES



Notes:
- Aerial: ESRI Basemap
- Coordinate System: NAD 1983 2011 StatePlane New Mexico West FIPS 3003 Ft US
- Projection: Transverse Mercator
- Datum: NAD 1983 2011

TITLE:

Site Location
Navajo North Area

LOCATION:

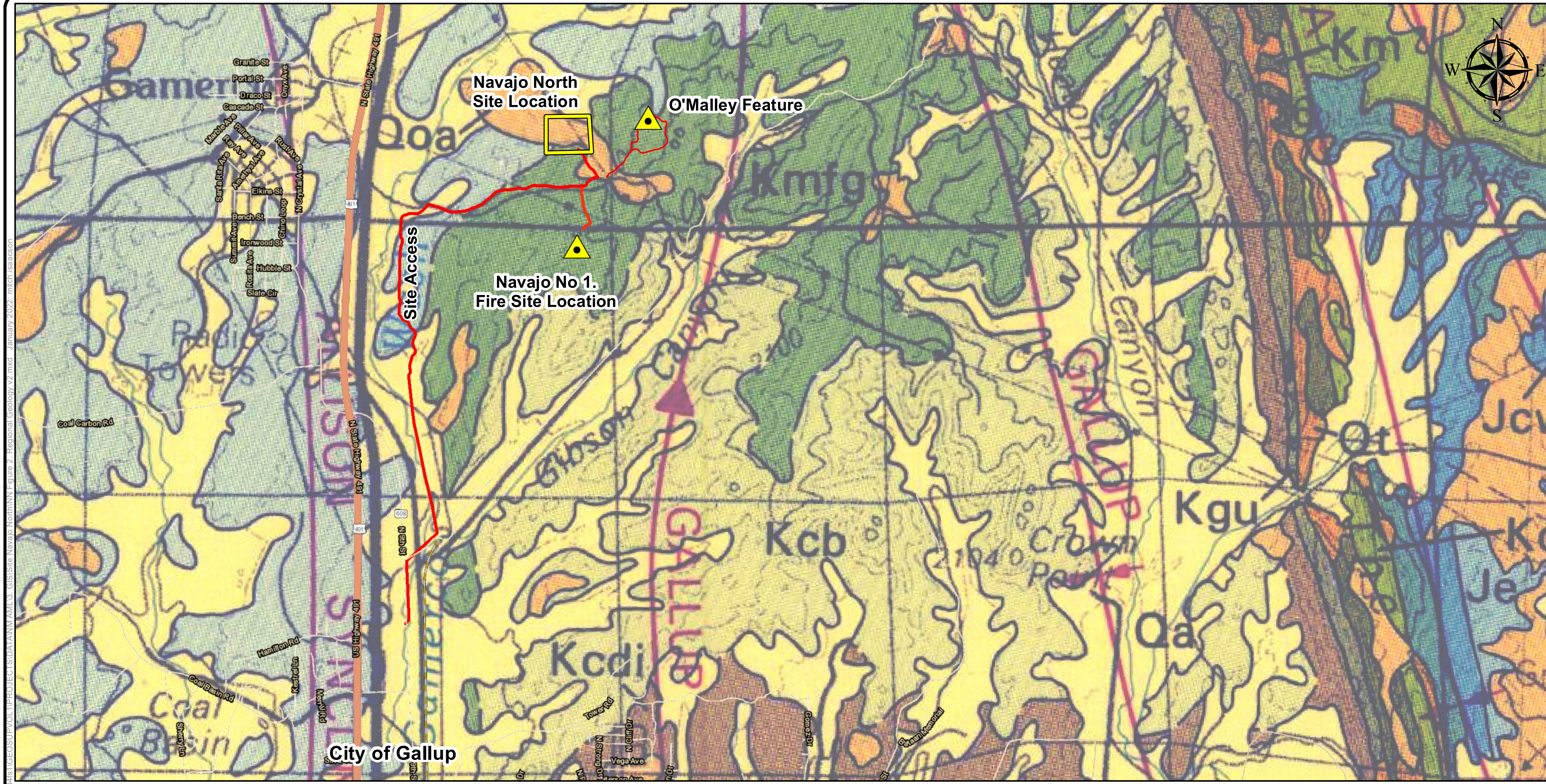
Gallup, Mckinley County, New Mexico

TETRA TECH

APPROVED	JN
DRAFTED	MRI
PROJECT#	117-0524316
DATE	1/13/2022

FIGURE

1



Geologic Legend

Kmfg	Cleary Coal Memeber of Menfee Formation and Gibson Member of Crevasse Canyon Formation, undivided
Kcb	Bartlett Barren Member of Crevasse Canyon Formation
Qao	Older alluvium and eolian deposits

0 500 1,000 2,000 3,000 4,000 5,000 ft

Notes:
- Geologic Map:Dillinger, J.K., 1990, Geologic map and structure contour maps of the Gallup 30' X 60' quadrangle, McKinley County, New Mexico, USGS, I-2009.
- Coordinate System: NAD 1983 2011 StatePlane New Mexico West FIPS 3003 Ft US
- Projection: Transverse Mercator
- Datum: NAD 1983 2011

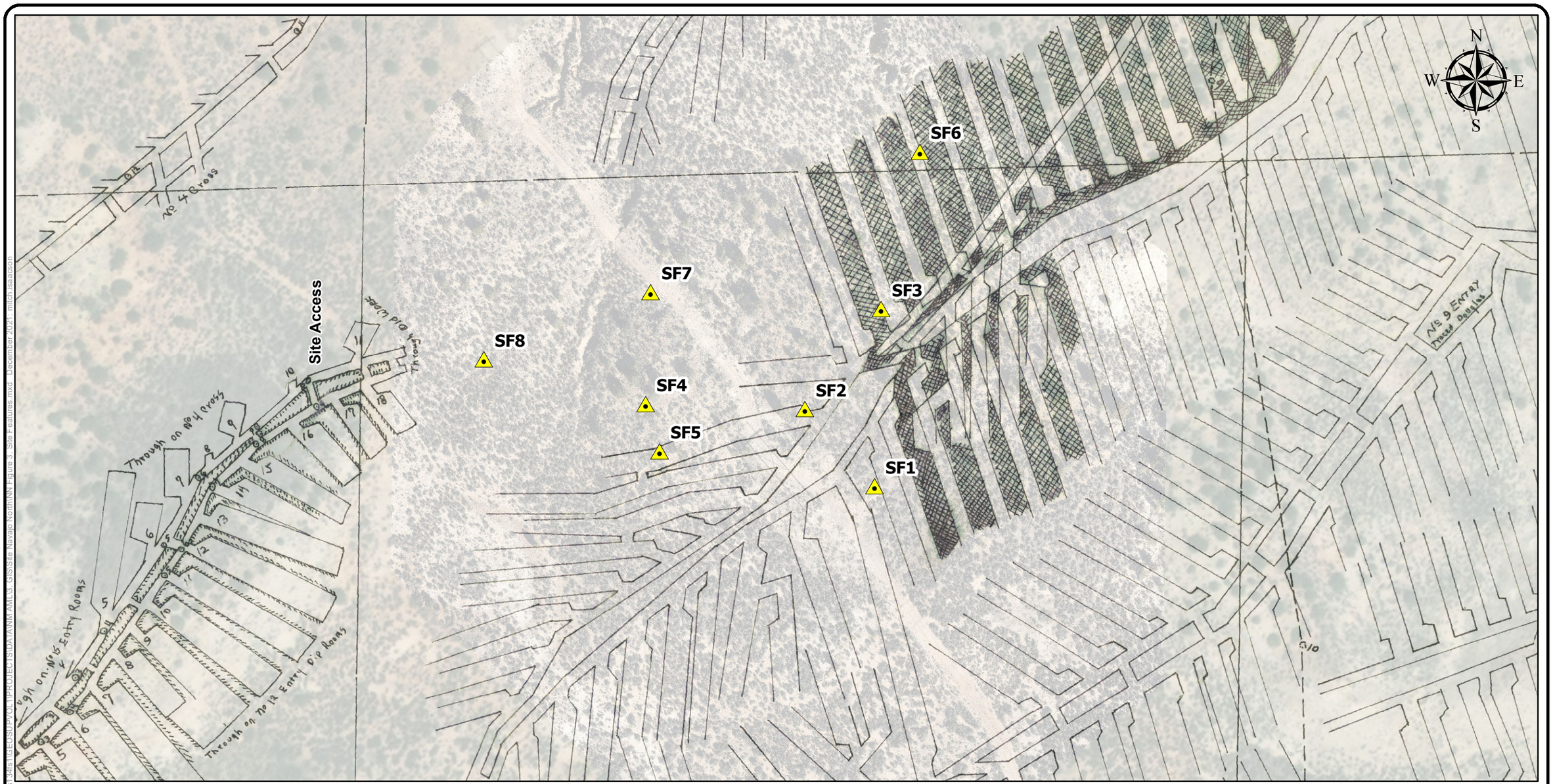
TITLE:
Regional Geologic Map
Navajo North Area

LOCATION:
Gallup, Mckinley County, New Mexico

TETRA TECH

APPROVED	JN
DRAFTED	MRI
PROJECT#	117-0524316
DATE	1/13/2022

FIGURE
2



Legend

- Site Features
- Historic Mine Workings Outlines

0 50 100 200 300 400 ft

Notes:
Historic Mine Workings: Gallup Mine Map No. 1405
Aerial: Tt Nov UAV Aerial and ESRI Basemap (background)
Coordinate System: NAD 1983 2011 StatePlane New Mexico West FIPS 3003 Ft US
Projection: Transverse Mercator
Datum: NAD 1983 2011

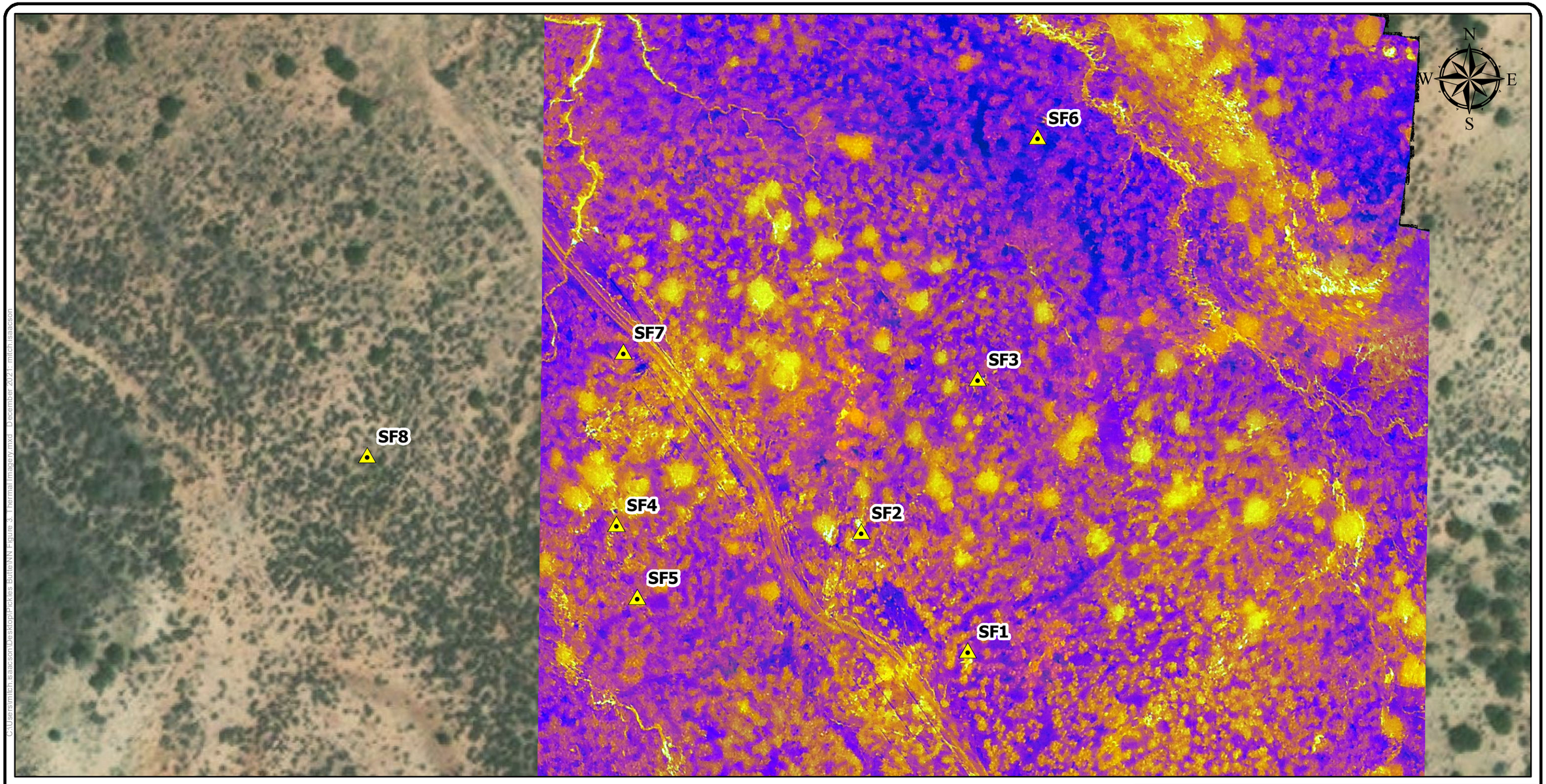
TITLE:
Site Features and Mine Map Navajo North Area

LOCATION:
Gallup, Mckinley County, New Mexico

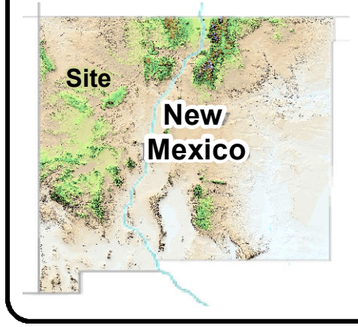
TETRA TECH

APPROVED	JN
DRAFTED	MRI
PROJECT#	117-0524316
DATE	12/10/2021

FIGURE
3



C:\Users\mich.isaacson\Desktop\Pickles Butte\NN Figure 3 - Thermal Imagery.mxd - December 2021 - mich.isaacson



Legend

Site Features

Thermal Imagery

8 34 (°F)

Notes:
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Projection: Transverse Mercator
Datum: NAD 1983 2011

0 25 50 100 150 200 ft

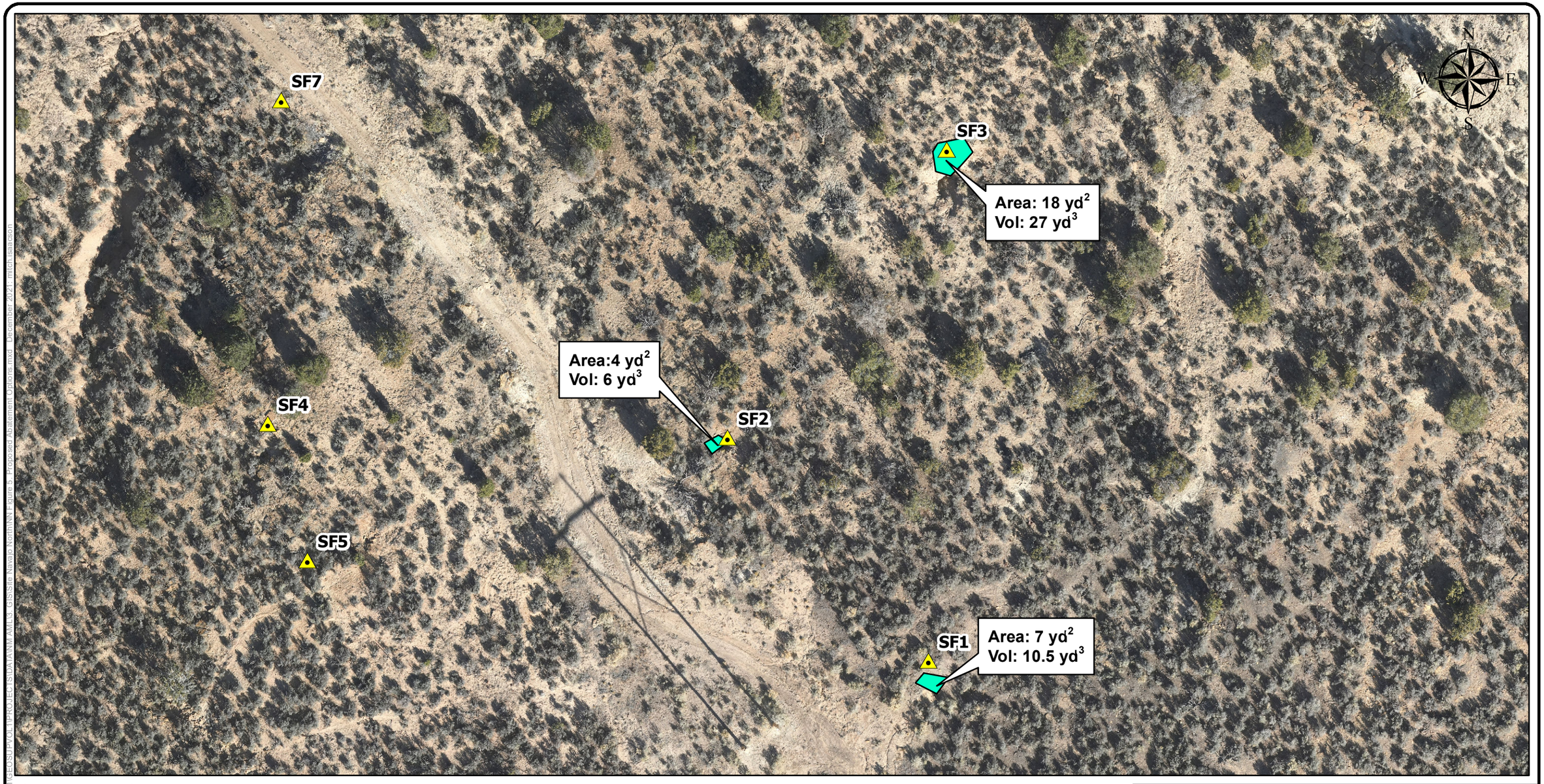
TITLE:
Thermal Imagery
Navajo North Area

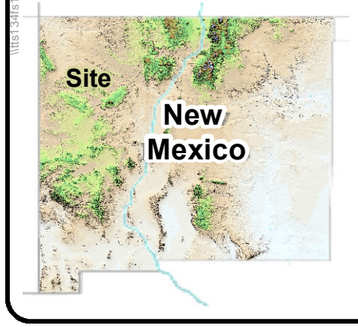
LOCATION:
Gallup, Mckinley County, New Mexico

TETRA TECH

APPROVED	JN
DRAFTED	MRI
PROJECT#	117-0524316
DATE	12/9/2021

FIGURE
4





Legend

- Site Features
- Mitigation Areas

Notes:
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Coordinate System: NAD 1983 2011 StatePlane New Mexico West FIPS 3003 Ft US
Projection: Transverse Mercator
Datum: NAD 1983 2011

0 25 50 100 150 ft

TITLE:
Proposed Abatement Options
Navajo North Area

LOCATION:
Gallup, Mckinley County, New Mexico

TETRA TECH

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PROJECT#	117-0524316
DATE	12/10/2021

FIGURE 5

Appendix A – Site Photographs

North Navajo Area - Gallup, NM
Tetra Tech Project No. 117-0524337

PHOTOGRAPH 1 Subsidence feature No. 1

PHOTOGRAPH 2 Subsidence feature No. 2

PHOTOGRAPH 3 Subsidence feature No. 2

PHOTOGRAPH 4 Subsidence feature No. 3

PHOTOGRAPH 5 Subsidence No. 4.

PHOTOGRAPH 6 Gas readings in Subsidence No. 5

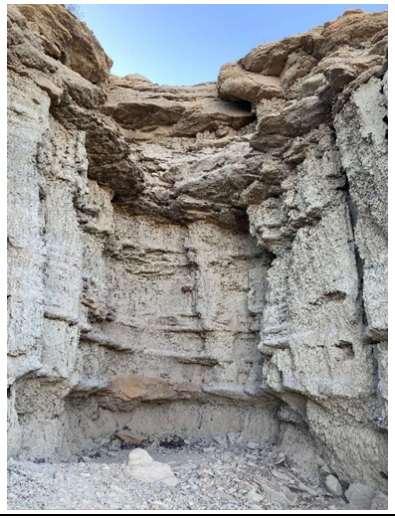
North Navajo - Coal Mine Fire Assessment
Gallup, NM
Tetra Tech Project No. 117-0524337

PHOTOGRAPH 7 Subsidence No. 6

PHOTOGRAPH 8 Subsidence No.7

PHOTOGRAPH 9 Subsidence No. 8

PHOTOGRAPH 10 O'Malley feature



PHOTOGRAPH 11 O'Malley feature

PHOTOGRAPH 12 Erodible layer with sandstone cap

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