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Geologic Hazards Study

Proposed Cody Central Gathering Facility

Southwest Corner of County Roads 6 and 15

Weld County, Colorado

Report No. 283926 has been prepared for:

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1. INTRODUCTION

In accordance with your request, TRC has performed a geologic hazards study for the proposed Hub Facility project located near the southwest corner of WCR 6 and WCR 15 in Weld County, Colorado. The purpose of our study was to evaluate the geologic hazards in the site vicinity by reviewing available documents and literature regarding geologic conditions at the project site. The conclusions provided in this report are intended for planning purposes. A preliminary geotechnical evaluation of the site in June 2017 and a design-level geotechnical evaluation, including subsurface evaluation and laboratory testing, were performed by Cole Garner Geotechnical, and results were presented in their report dated December 11, 2017.

2. SCOPE OF SERVICES

The scope of our geologic hazards study included the following:

- Review of pertinent background data listed in the *References* section of this report. The data reviewed included geotechnical data, aerial photographs, abandoned coal mine subsidence maps, and published geologic maps and literature.
- Compilation and analysis of the accumulated data.
- Preparation of this geologic hazards study report presenting our findings and conclusions.

3. PROJECT DESCRIPTION

The subject site includes approximately 156 acres of primarily vacant agricultural land located at the southwest corner of Weld County Roads 6 and 15 in unincorporated Weld County, Colorado. Five existing oil and gas well sites and other equipment are present within the larger parcel being evaluated. We understand that the client will be developing the property as a new natural gas gathering and processing facility. At the current time, planning for the site is in the early design stages, however, we understand that the plant will include the installation of equipment such as compressors, pumps, storage vessels, gas flare, and pipe rack assemblies. We assume that an MCC Building and additional small outbuildings will also be constructed. We assume that structural compressive loads will range from about 10 to 50 kips for pipe rack supports and smaller equipment, and up to about 100 to 200 kips for heavier equipment and taller flare structures.

Grading plans were being developed at the time this report was prepared, however, we estimate that site grading may include earthen cuts and fills of up to about 5 to 10 feet to bring the site to construction grade (exclusive of any mitigation required). Construction will also include paved and/or gravel surfaced access drives, as well as some limited site landscaping.

4. GENERAL SITE CONDITIONS

The site is bordered by Weld County Road 6 to the north, Weld County Road 15 to the east, and agricultural land to the south and west. At the time of the field exploration, the ground surface was mostly covered with a low growth of grass and weeds along with some areas of plowed field. An existing natural drainage area is

present at the site and flows from the west-central portion of the property toward the southeast corner of the site. Multiple oil and gas wells (along with buried pipelines) are present across the site. An unpaved well access road is present off of Weld County Road 15. An overhead electric utility is also present across the site. Based on provided plans, the site slopes downwards to the southeast (as well as towards the existing drainage), with an estimated elevation differential of about 60 feet across the site.

5. REGIONAL GEOLOGIC SETTING

The project site is located approximately 18 miles east of the southern Rocky Mountains, within the Colorado Piedmont section of the Great Plains Physiographic Province. The Town of Erie, about 6.8 miles west of the site, is located near the northern margins of a large north-south trending structural basin called the Denver Basin. The Denver Basin formed during the Laramide Orogeny that uplifted the Rocky Mountains during the late Cretaceous and early Tertiary (Trimble, 1980). Over time, the Denver Basin filled with alluvial sediments and wind-blown eolian deposits. The underlying bedrock is comprised of Tertiary to Cretaceous-age sedimentary units.

6. SITE GEOLOGY

The surficial geology of the site is mapped by Colton (1978) as Holocene to late Pleistocene-age Eolian Deposits (wind-blown) including dune sand and loess deposits, which were deposited in the post-glacial period. The mapped geology at the site is presented on Figure 2. The Eolian Deposits are generally composed of silt and clay with varying amounts of sand. The underlying formational bedrock unit is mapped as the Upper Cretaceous-age Laramie Formation consisting of an upper and a lower part. The upper part is described as mostly gray claystone, shale, sandy shale, and lenticular beds of sandstone and lignite. The lower part is described as light gray to light yellowish gray sandstone and sandy shale interbedded with clay, shale, and several beds of coal.

Based on the exploratory borings performed at the site the overburden soils across the site primarily consist of lean clays with varying amounts of sand. Clayey sands were also encountered underlying the clays in borings in the general vicinity of the existing drainage. Sedimentary claystone and sandstone bedrock was encountered underlying the clays/sands at depths ranging from about 7 to 14 feet in the southwest and northeast portions of the site, and at depths ranging from about 12 to 24 feet in the central areas of the site nearer the existing natural drainage . The bedrock extended to the maximum depths explored of 50 feet.

Field and laboratory test results from the CGG investigation indicate that the clay soils vary from soft to hard in consistency. The clayey sand soils vary from loose to medium dense in relative density. Laboratory test results indicate that the clayey soils exhibit moderate plasticity. Select samples of the clay soils exhibited low expansive potential at existing moisture contents under light loads. When loaded further these clay samples generally exhibited moderate consolidation potential. Select samples of the claystone generally exhibited moderate to high expansion potential.

Testing of select soil and bedrock samples for water-soluble sulfates indicated concentrations ranging from 400 to 1,900 parts per million (ppm). On this basis, we judge the soils to have negligible to moderate corrosion potential to buried concrete structures. Laboratory test results indicate that the lean clay soils sampled at shallow depths have resistivity values ranging from 800 to 4,100 ohm-centimeters, and pH values ranging from 8.0 to 9.1. These values indicate very severe to moderately severe corrosion potential to buried metallic structures.

7. GROUNDWATER

Groundwater was encountered in the borings drilled as a part of the geotechnical investigation immediately after drilling at depths ranging from about 6 to 27 feet below existing site grades. When checked a

minimum of one week later, groundwater was measured in the borings at depths ranging from about 5 to 15½ feet below existing site grades for most of the site. In the preliminary geotechnical study of the site (June 2017), groundwater ranged from about 2 to 7½ feet below existing site grades for most of the site.

Based upon review of U.S. Geological Survey Maps (Hillier, et al.,1979), regional groundwater beneath the project site occurs in colluvial or windblown deposits, or in consolidated sedimentary bedrock at depths generally ranging from 5 to 20 feet below existing grade, with depth to seasonal groundwater generally less than 10 feet below present ground surface.

Seasonal fluctuations in groundwater levels and surface water flow may occur. These fluctuations may be due to variations in ground surface topography, subsurface geologic conditions, rainfall, irrigation, and other factors. Evaluation of factors associated with groundwater fluctuations was beyond the scope of this study.

8. POTENTIAL GEOLOGIC HAZARDS

This evaluation included visual observation of the site for indications of adverse geologic features and review of published geologic maps and literature, and other data listed in the References section of this report. Referenced geologic data were also reviewed to evaluate seismic activity levels, and associated potential earthquake hazards, for faults in the vicinity of the site.

8.1. Faulting and Seismicity

Based on our review of readily available published geological maps and literature, there are no known active faults underlying or adjacent to the subject site. A number of older faults are mapped in the site vicinity as concealed or inferred beneath the overlying Eolian Deposits or as faults within the Laramie Formation (Colton, 1978). The closest questionable Quaternary-age fault to the site is the Golden Fault, which lies approximately 22 miles to the south-southwest(USGS & CGS, 2013). The fault is considered to be of questionable origin and has not shown displacement in Holocene time. Therefore, the probability of damage at the site from seismically induced ground surface rupture along this or other, more distant Quaternary faults is considered to be low.

Historically, several minor earthquakes have been recorded near the Weld County area. Using the referenced United States Geological Survey (USGS) seismic web application (USGS, 2012), estimated maximum considered earthquake spectral response accelerations for short (0.2 second) and long (1.0 second) periods were obtained for the project site. Based on the findings of CGG's subsurface exploration program and the International Building Code developed by the International Code Council (ICC, 2012), a site specific Seismic Site Class D is appropriate for the project site. The parameters in the following table are characteristic of the project site for design purposes.

8.2 Maximum Estimated Ground Shaking

Based on Equation 11.8-1 of ASCE 7-10, a maximum considered earthquake geometric mean peak ground acceleration of 0.14g, can be expected at the site.

8.3 2009 International Building Code (IBC) Site Seismic Coefficients

Chapter 16 of the 2012 IBC outlines the procedure for seismic design of structures. The site is generally underlain by very stiff to hard clays, dense sand, which correspond to a soil profile type D. Based on this information and local seismic sources, the site may be characterized for design using the information in Table 1 below.

Table 1. 2012 IBC Site Class and Site Seismic Coefficients

Latitude: 40.0273 N Longitude: 104.9272 W	**IBC Table/Figure**	**Factor/ Coefficient**	**Value**
Soil Profile Type	Table 1613.3.2	Site Class	D
Mapped Spectral Response Acceleration for MCE at 0.2 second Period	Figure 1613.3.1(1)	S_S	0.17
Mapped Spectral Response Acceleration for MCE at 1 Second Period	Figure 1613.3.1(2)	S_1	0.06
Site Coefficient	Table 1613.3.3(1)	F_a	1.65
Site Coefficient	Table 1613.3.3(2)	F_v	2.39
Adjusted MCE Spectral Response Parameter	Equation 16-37	S_{MS}	0.28
Adjusted MCE Spectral Response Parameter	Equation 16-38	S_{M1}	0.14
Design Spectral Acceleration Parameter	Equation 16-39	S_{DS}	0.19
Design Spectral Acceleration Parameter	Equation 16-40	S_{D1}	0.09

8.4 Liquefaction

During cyclic ground shaking, such as earthquakes, cyclically-induced stresses may cause increased pore water pressures within the soil matrix, which results in liquefaction. Liquefied soil may lose shear strength that may lead to large shear deformations and/or flow failure (Youd et al., 2001). Liquefied soil can also settle as pore pressures dissipate following an earthquake. Limited field data is available on this subject; however, settlement on the order of 2 to 3 percent of the thickness of the liquefied zone has been measured in some cases.

Soils most susceptible to liquefaction are loose to moderately dense, saturated, non-cohesive soils with poor drainage, such as sands and silts with interbedded or capping layers of relatively low permeability soil.

Based on the exploratory borings, the site is underlain by very stiff to hard lean clay and dense clayey sand, and relatively shallow bedrock. Although the groundwater is at relatively shallow depths, the estimated site acceleration value is relatively low. Therefore, we judge the potential for liquefaction damage to the proposed improvements at the site to be low.

8.5 Dry Seismic Settlement

If near-surface soils vary in composition both vertically and laterally, earthquake shaking can cause non-uniform densification of loose to medium dense cohesionless soil strata. This results in movement of the near-surface soils. The borings did not encounter any loose to medium dense cohesionless soil strata above the groundwater level. Therefore, we judge the probability of significant differential settlement of non-saturated granular layers at the site to be low.

8.6 Landsliding

Although there is approximately 60 feet of elevation difference across the site, because of the relatively flat topography of the project site, we judge that the potential for landsliding is considered negligible for the site.

8.7 Lateral Spreading

Lateral spreading typically occurs as a form of horizontal displacement of relatively flat-lying alluvial material toward an open or "free" face such as an open body of water, channel or excavation. In soils, this movement is generally due to failure along a weak plane and may often be associated with liquefaction. As cracks develop within the weakened material, blocks of soil displace laterally towards the open face. Cracking and lateral movement may gradually propagate away from the face as blocks continue to break free. Generally, failure in this mode is analytically unpredictable since it is difficult to evaluate where the first tension crack will occur.

Because the potential for liquefaction at the site is considered to be low, we judge the risk of lateral spreading at the site to also be low.

8.8. Mine Subsidence Hazards

The Boulder-Weld Coal Field in the Erie, Colorado area has experienced numerous instances of damage to structures and infrastructure related to mine subsidence from abandoned mine workings. The Erie, Colorado area experienced a heavy period of mining, both surface and subsurface, from the 1800's through the late 1970's. We have reviewed numerous background documents (see the *References* section of this report) related to previous mining activity and subsidence-related hazards. Review of referenced topographical maps and published maps depicting areas of coal extraction and mine subsidence hazards indicate past mining activities to the north and west of the project site. The location of the site relative to mapped coal mine subsidence hazards is presented on Figure 3.

We have evaluated the potential for subsidence hazards due to possible collapse of the subterranean mine workings in the site vicinity and it is our opinion that the likelihood of subsidence related hazards to the proposed improvements is negligible.

8.8.1 Lincoln Mine

The area northwest of the subject site was the location of the Lincoln Mine, which was mined from the 1940's to the mid 1970's. The nearest subterranean mine workings of the Lincoln Mine are approximately 2,000 feet northwest of the project site. The Lincoln Mine was a subterranean mine that extracted coal from relatively flat-lying coal seams within the Laramie Formation. Based on our review of information from the Colorado Mine Subsidence Information Center (2013) and Roberts et al. (2001), the depth of the coal mine workings was 300 to 400 feet below the ground surface. Therefore, the subsidence hazard at the site from the collapse of subterranean voids related to mining of the Lincoln Mine is considered low.

8.9. Compressible/Collapsible Soils

Compressible soils are generally comprised of soils that undergo consolidation when exposed to new loadings, such as fill or foundation loads. Soil collapse (or hydro-collapse) is a phenomenon where the soils undergo a significant decrease in volume upon an increase in moisture content, with or without an increase in external loads. Buildings, structures, and other improvements may be subject to excessive settlement-related distress when compressible soils or collapsible soils are present. Based on our review of published geologic maps of the site, we understand that the site is underlain by Eolian Deposits, composed of loess and dune deposits, which are known to be subject to settlement from compressible or collapsible soils. Geotechnical laboratory testing for the site indicated low to moderate collapse potential and low to moderate compressibility of the soils.

8.10. Expansive Soils/Bedrock

One of the more significant geologic hazards in the Front Range area is the presence of swelling clays in bedrock or surficial deposits. Wetting and drying of bedrock or surficial deposits containing swelling clays can result in expansion and collapse of those units, which can cause major damage to structures. A review of a Colorado Geological Survey map delineating areas based on their relative potential for swelling in the site vicinity by Hart (1973-4) indicates that the soil and bedrock materials in the site vicinity have "High" swell potential. The results of the geotechnical laboratory testing indicated moderate to high expansion potential, with swells of up to 6 percent and expansion pressures of up to 10,000 psf.

8.11. Other Geologic Hazards

Ground fissures, generally believed to be caused by erosion and differential stress resulting from regional subsidence due primarily to withdrawal of groundwater, are known to occur in Colorado. Review of referenced geologic data does not indicate the presence of ground fissures at the project site and no ground fissures were noted during previous field activities. The potential for hazards from ground fissures is considered negligible at the site.

The site is located in an area designated as Zone X, area of minimal flood hazard on FEMA Map 08123C2100E. Detailed flood zone evaluation should be performed by the project Civil Engineer.

9. PRELIMINARY CONCLUSIONS

Based on our review of referenced geotechnical, geologic, seismologic and abandoned coal mine subsidence data, it is our opinion that there are no known geologic hazards that would preclude development of the Cody Central Gathering Facility project at the proposed site. The conclusions provided in this report should be considered preliminary and are intended for planning purposes. The design-level geotechnical evaluation, including subsurface evaluation and laboratory testing, will need to be followed for design and construction of the proposed improvements at the site. Preliminary findings of this geologic hazard evaluation include the following:

- The subject site is considered suitable for the construction of the Cody Central Gathering Facility project, from a geotechnical perspective.
- Geologic hazards such as on-site faults, liquefaction, ground fissures, flood-prone areas, landslides or unstable slope hazards were not indicated in the referenced publications.
- The subject site is mapped in an area of low risk for mine subsidence. No evidence of abandoned mine workings are indicated beneath the site, based on our review of available documents.

- The site is mapped as being underlain by Eolian Deposits which are in turn underlain by bedrock of the Laramie Formation. The Eolian Deposits consist of wind-blown loess and dune deposits, composed of silt, clay, and sand. The Laramie Formation in the site vicinity consists of gray claystone, shale, sandy shale, and lenticular beds of sandstone and lignite.

- Some of the near-surface Eolian Deposits are potentially moisture-sensitive and may be prone to settlement from compressible or collapsible soil conditions. These soils will likely not be suitable for support of structures and improvements in their existing condition. Shallow foundations, slabs-on-grade, exterior concrete flatwork, pavement sections, and other improvements will likely need to be founded on a zone of adequately placed and compacted engineered fill. The depth, lateral extent, and compaction levels were specified in the design-level geotechnical evaluation.

- The site is mapped in an area of "High" risk of hazards from expansive soil and bedrock. The expansion potential of the soil was evaluated and geotechnical recommendations for the mitigation of expansive soil and bedrock conditions were provided in the design- level geotechnical evaluation.

- Adequate surface drainage should be provided to reduce ponding and infiltration of water into the subsurface soils. Surface runoff from surrounding areas should be intercepted, collected, and not permitted to flow or infiltrate into subsurface soils. Consideration should be given to utilization of swales, edge drains, building roof drains, tightlined downspouts, curbs and gutters, or combination of these drainage devices, to reduce the adverse effects of surface water runoff.

- Sulfate and electrical resistivity tests have been performed. The native on-site soils are considered to have negligible to moderate corrosion potential to buried concrete structures and moderate to very severe corrosion potential to buried metallic structures. Soil blending or replacement, and/or utilization of materials that are resistant to corrosion should be anticipated for the project.

- Information from exploratory borings at the site indicates groundwater beneath site as shallow as 2½ feet bgs. Static aquifer groundwater levels measured previously in wells in the site vicinity indicate that the groundwater table may be on the order of 50 or more feet below the existing ground surface.

- The preliminary seismic site classification was assumed to be Site Class "D".

- Ground elevations at the proposed site range from approximately 5,120 to 5,063 feet above mean sea level (MSL). An appropriate frost depth will need to be established for the design of site structures.

10. LIMITATIONS

This report has been prepared for the sole use of XTR Midstream, LLC, specifically to evaluate geologic hazards that would affect the design of the proposed Cody Central Gathering Facility at the southwest corner of County Roads 6 and 15 in Weld County Colorado. The opinions, conclusions, and recommendations presented in this report have been formulated in accordance with accepted geological and geotechnical engineering practices that exist in that area at the time this report was written. No other warranty, expressed or implied, is made or should be inferred.

The opinions, conclusions and recommendations contained in this report are based upon the information obtained from our investigation, which includes data from widely separated discrete locations,and review of other geotechnical data provided to us, along with engineering judgment. The recommendations presented in this report are based on the assumption that soil and geologic conditions at or between borings do not

deviate substantially from those encountered or extrapolated from the information collected during our investigation. We are not responsible for the data presented by others.

The opinions presented in this report are valid as of the present date for the property evaluated. Changes in the condition of the property will likely occur with the passage of time due to natural processes and/or the works of man. In addition, changes in applicable standards of practice can occur as a result of legislation and/or the broadening of knowledge. Furthermore, geotechnical issues may arise that were not apparent at the time of our investigation. Accordingly, the opinions presented in this report may be invalidated, wholly or partially, by changes outside of our control. Therefore, this report is subject to review and should not be relied upon after a period of three years, nor should it be used, or is it applicable, for any other properties.

This report is intended for preliminary evaluation purposes only. It does not provide sufficient data for design purposes.

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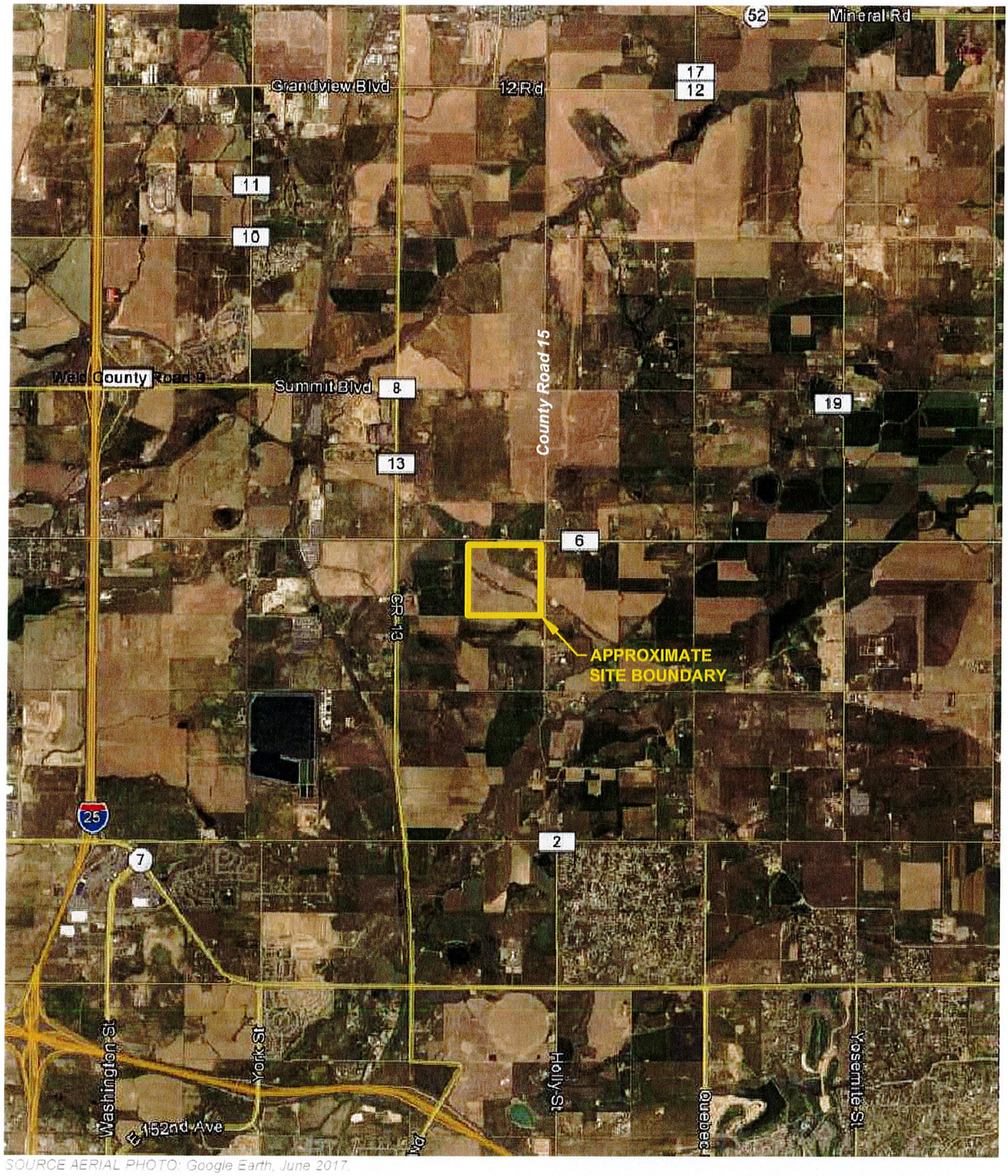


SOURCE AERIAL PHOTO: Google Earth, June 2017.

N

APPROXIMATE SCALE (MILES)

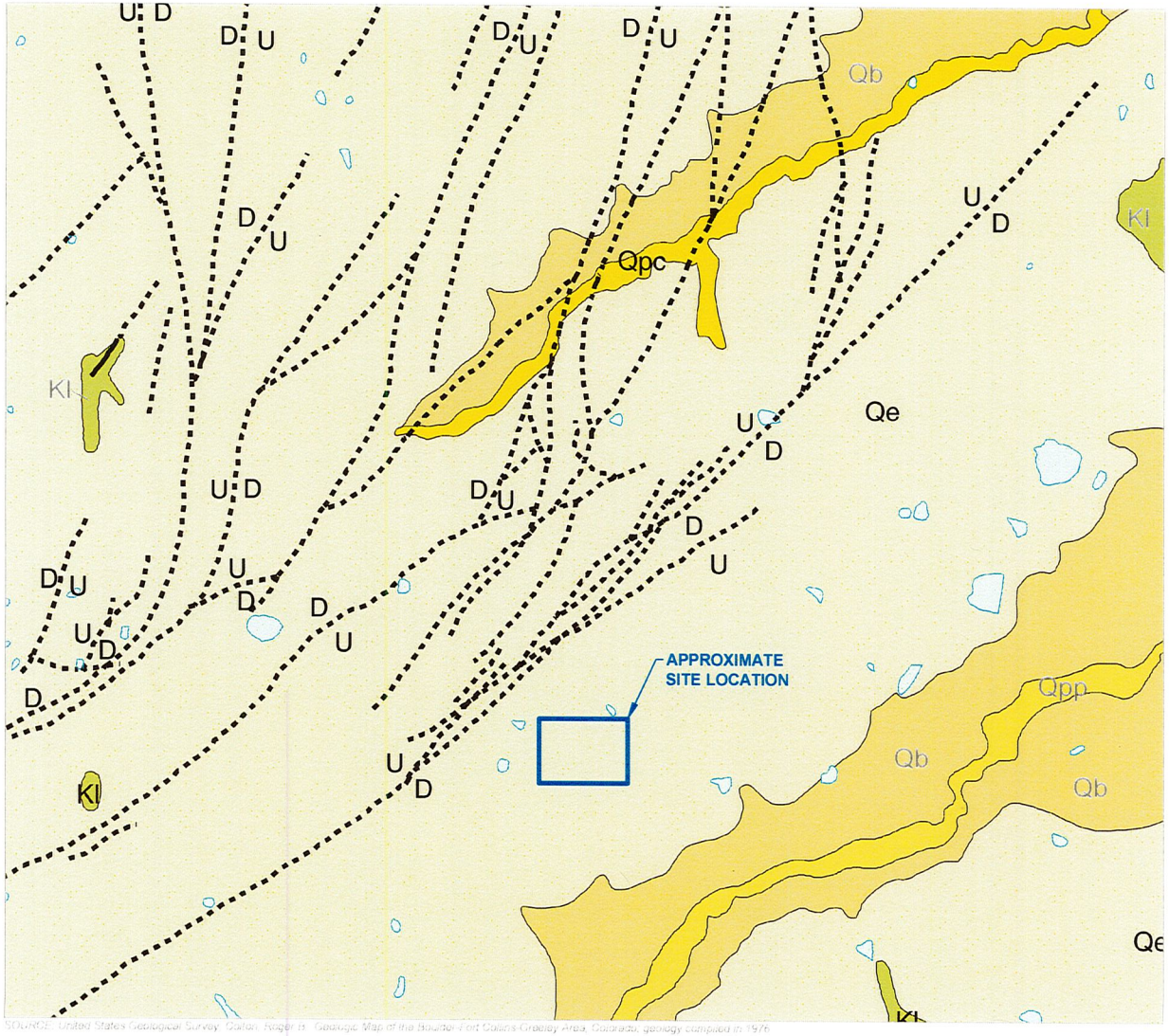
0 1 2

VICINITY MAP

Cody Central Gathering Facility
County Roads 6 and 15
Weld County, Colorado

TRC | 283926 | **FIGURE 1**

FILE NAME: Z:\Shared\CAD_DRAWS\current\Cody Central Gathering Facility\Fig1_Vicinity Map.dwg | Layout Tab: 8x11



SOURCE: United States Geological Survey, Dalton, Roger B. "Geologic Map of the Boulder-Fort Collins-Greeley Area, Colorado, geology compiled in 1976

LEGEND

Qpp	Post-Piney Creek alluvium
Qe	Eolium (windblown clay, silt (loess), sand, and granules)
Qpc	Piney Creek alluvium
Qb	Broadway alluvium
Kl	Laramie Formation
———	Contact
U / D	Fault or linear feature inferred to be a fault: Dotted where concealed U - upthrown side D - downthrown side

N

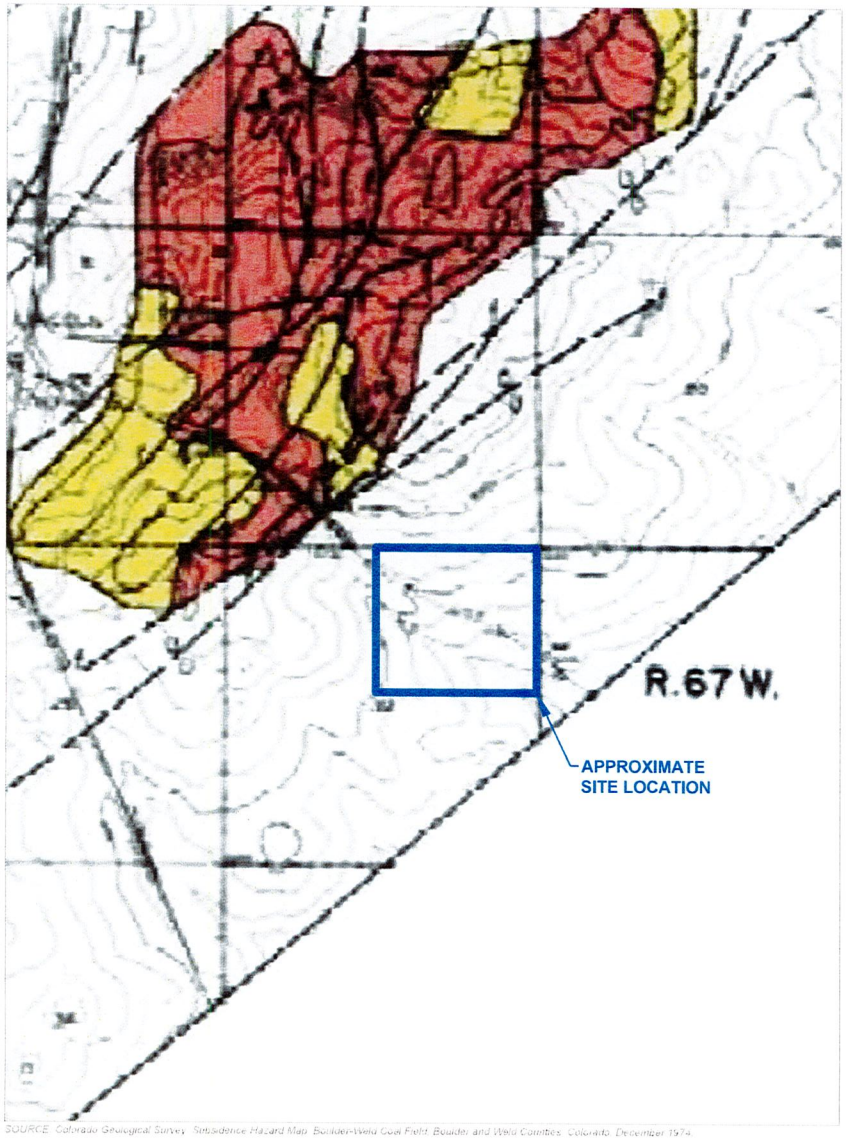
APPROXIMATE SCALE (FEET)

0 3,000 6,000

GEOLOGIC MAP

Cody Central Gathering Facility
County Roads 6 and 15
Weld County, Colorado

TRC 283926 **FIGURE 2**



SOURCE: Colorado Geological Survey, Subsidence Hazard Map, Boulder-Weld Coal Field, Boulder and Weld Counties, Colorado, December 1974.

LEGEND

Subsidence hazard:

- Severe
- Low

N

APPROXIMATE SCALE (FEET)

0 2,000 4,000

MINE SUBSIDENCE MAP

Cody Central Gathering Facility
County Roads 6 and 15
Weld County, Colorado

TRC | 283926 | **FIGURE 3**