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July 17, 2019

Margaret Ash
Colorado Oil and Gas Conservation Commission
1120 Lincoln Street, Suite 801
Denver, Colorado 80203

RE: Laramie Professional Slope Stability Evaluation
Cascade Creek 604-12-13 Annex COGCC Location ID#424970

Dear Margaret Ash;

As per Laramie Energy, LLC's (Laramie) letter dated Feb 12, 2019, Laramie is providing you with our slope stability evaluation for the 604-12-13 Annex location. The evaluation was also intended to assess the need for slope stabilization via the incorporation of erosion control blanketing.

The report was prepared by professional engineers from Geotechnical Water Resources Environmental and Engineering Services (GEI) and is attached to this submittal.

The summary of findings is as follows:

"Therefore, in the event of a 100-year storm, we believe that there will be no offsite transportation of material. Smaller events will have less to no runoff, and given that vegetation will continue to establish on the slope, GEI believes that no erosion blanket is necessary to prevent offsite migration of material prior to implementation of interim site reclamation."

If you have any questions related to these findings, please contact me.

Yours,

Lorne C. Prescott
Regulatory and Environmental Compliance
Laramie Energy, LLC
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lprescott@laramie-energy.com

cc: W. Bankert, C. Clark

Memorandum

To: Matt Hall, P.E.
Facilities Engineering Manager
Laramie Energy, LLC
1401 17th Street Suite 1400
Denver, CO 80202

From: Jeremy Deuto, P.E., P.G., Ben Taylor, P.E.

Date: July 9, 2019

Re: **12-13 Annex Well Pad Stability Evaluation**

GEI Consultants, Inc. (GEI) has prepared this technical memorandum to summarize the results of a stability evaluation performed for the Laramie Energy 12-13 Annex Well Pad in western Colorado (Figure 1). The Colorado Oil and Gas Conservation Commission (COGCC) has noted concerns with global pad and geomorphological slope stability at the site, and this evaluation was performed to address those concerns.

GEI performed several site reconnaissance visits to evaluate the area from a geological perspective and to gather hands-on information about the conditions and characteristics of the well pad construction and materials present within the pad fill. Information collected during the site visits was used to develop model parameters and calibrate the model to the field-based conditions.

SITE LOCATION AND DESCRIPTION

The 12-13 Annex is a gas production well pad located in Garfield County, approximately 16 miles north of the town of DeBeque, CO at an elevation (El.) of 8529. The approximate 4.4 acre well pad (8.3-acre disturbed area) was constructed in 2011 and is currently owned and operated by Laramie Energy, LLC (Laramie).

SITE RECONNAISSANCE

GEI performed two field surveys of the 12-13 Annex Well Pad, on May 29, 2019 and June 19, 2019. During the May 29, 2019 site visit, we performed an Unmanned Aerial Systems (UAS) flight to capture geo-oriented photography and develop an accurate, up-to-date topographic survey of the well pad area and to obtain aerial photography to assist with the stability evaluation. The geo-oriented photographs were used to generate a photogrammetric model and topographic contours the well pad (Figure 2). All UAS flights were performed in accordance with Federal Aviation Administration (FAA) regulations by a licensed remote pilot

who maintained a visual line-of-sight with the Unmanned Aerial Vehicle (UAV). A single flight was necessary to obtain the required photographs to generate topographic contours.

After the site visit, GEI uploaded photos of the 12-13 Annex Well Pad area into Pix4D software to generate the photogrammetric model. Pix4D uses matching keypoints in overlapping photographs to tie the information together and develop a three-dimensional (3D) mosaic of the site photographs. The 3D model is then used to generate elevation contours for the site, which is exported for use in AutoCAD Civil3D and used to create representative site topography for the stability evaluation.

During the May 29, 2019 site visit, GEI conducted a visual inspection of accessible areas on, above, and downhill of the existing well pad. These observations were intended to gather additional data as it relates to the global slope stability of the pad. During the June 29, 2019 site visit, GEI conducted a visual inspection of the face of the fill slope to develop an understanding of the erosional potential of the fill material, existing erosional conditions of the fill slope, and conditions present at the toe of the fill slope. No subsurface geotechnical investigation or laboratory testing was conducted as part of this evaluation.

WELL PAD CONDITIONS

The well pad is assumed to have been constructed from fill materials obtained from the blasted cut slope and is reported to be large diameter (+6-inch) angular material with limited silty sand fines interspersed throughout. The exposed face of the fill slope appears to confirm this assumption, although our observations suggest there is an increased percentage of fines resulting from localized reclamation operations conducted by Laramie and/or by in-situ weathering of the material. The topographic model developed by the UAS indicates that the well pad itself is relatively flat with a general overall drainage slope of 0.8% or less. The fill slope of the well pad is oriented at approximately 1.3:1 (H:V) and sparsely vegetated. There are very minor erosional rills present on the slope, most of which do not extend to the toe, and typically terminate after approximately 15-20 feet (Figure X). There is no accumulation of fine material within the catch basin constructed at the toe of the slope. These scenarios suggest a high infiltration rate of the well pad materials.

GLOBAL PAD SLOPE STABILITY

Slope Stability Analysis Model

GEI performed a slope stability analysis using the Slope/W v.9.0.4 software program by Geo-Slope International. Inputs for engineering properties of site soils were based on field observations of the in-situ materials and correlation with laboratory derived values of similar materials provided in Soil Strength and Stability, Second Edition (Duncan, Wright and Brandon, 2014).

A single profile was developed for the current 12-13 Annex Well Pad conditions using effective strength parameters. The UAS topography was used for the surface profile of the well pad and the adjacent slopes which are northeast and southwest of the well pad. These slopes are assumed to be native and unimpacted by construction, and the profile of these slopes was projected underneath the well pad topography to develop an assumed pre-construction

surface. Two distinct groundwater conditions were modeled to reflect dry and wet conditions at the site (both of which are estimated). A surcharge of 150 pounds per cubic foot (pcf) was added to the outermost edge of the well pad fill slope to represent loading from a 50-foot long and 15-foot high structure such as frack water tanks, drill equipment, etc.

Results of the stability analysis are given in terms of a factor of safety, which is the ratio of forces resisting landslide movement to the forces contributing to landslide movement. A factor of safety (FOS) of 1.0 or less indicates a potential or incipient failure condition.

For each scenario, Slope/W created 2200 failure planes (slip circles) and calculated the factor of safety. The Spencer method of slope stability involves dividing the failed slope into a number of slices, and produces a factor of safety that is equivalent for the forces involved on each slice and the moments generated by each slice. The Spencer approach uses a factor of safety that correlates more closely with observations of actual slope failure, and provides a realistic factor of safety. The Spencer factor of safety is listed on the annotated cross-section (Figure X). Seismic conditions were not modeled.

The modeled engineering properties of the overburden and well pad fill were selected from the conservative end of value ranges typical of blasted angular rockfill slopes. Modeled engineering property inputs are summarized in Table 1 and stability results are presented in Table 2.

Table 1: Modeled Critical Engineering Properties

Soil Unit	Unit Weight (pcf)	Cohesion, c' (psf)	Friction Angle, Φ (degrees)
Overburden	120	10	37
Platform Fill	125	0	44
Shale Bedrock	Impenetrable Bedrock Conditions		

Definitions

Φ' = effective stress angle of internal friction

c' = effective stress cohesion

pcf = pounds per cubic foot

psf = pounds per square foot

Table 2: Stability Results

Condition	Modeled Groundwater Depth ¹ (ft)	Factor of Safety
Existing Conditions	27	1.4
Existing Conditions (High Groundwater)	12	1.3

1 – Measured 40 feet from pad crest

Slope Stability Analysis Results

The modeled profile for the as-built condition closely resembles the field conditions of the pad slope at the times of site reconnaissance. We consider the slope to be at or slightly above a FOS of 1.4 for dry conditions and 1.3 for wet conditions, and that the modeled slope geometry,

groundwater depth, and engineering properties are reasonable representations of existing conditions. A factor of safety of 1.3 is considered across the industry to be the minimum acceptable factor for small-scale potential slope failures (U.S. Bureau of Reclamation 2011; U.S. Army Corps of Engineers 2003).

GEOMORPHOLOGICAL EVALUATION

GEI evaluated the well pad slope with respect to off-site sediment migration during precipitation events. To estimate the assumed precipitation values for the site, GEI reviewed data from the nearest representative weather station, located in Meeker, CO (Piceance Creek Station) approximately 40 miles northwest of the site. The weather station indicated a high average monthly precipitation value of 1.64 inches in May and the lowest average monthly precipitation value of 0.82 inches in January.

Given that the pad was constructed in 2011 and the slope face shows relatively minor erosion and transportation of material (non-continuous erosional rills, no sediment accumulation at the toe, etc), GEI assumes that most precipitation infiltrates the subsurface during rain events.

Without onsite monitoring, GEI cannot quantify the amount and duration of precipitation experienced onsite. Therefore, we developed a model of a 100-year precipitation event to compare anticipated runoff volumes with the estimated storage capacity of the catch basin at the toe of the slope.

GEI estimated the stormwater retention capacity of the ditch running along the toe of the fill slope using the topographic data collected by the unmanned aerial system (UAS). We made the following assumptions for estimating the ditch volume and the 100-year storm event runoff volume:

- Catch basin average depth of 30 inches (conservative)
- Catch basin area is approximately 28,500 square feet
- Riprap porosity of 0.29 (conservative)
- 100-year storm produces a precipitation total of 1.63 inches over 1 hour (conservative)
- Area contributing stormwater flows includes half of the pad, all of the fill slope, and some of the uphill native slopes (conservative)
- Runoff coefficient of 0.5 (conservative for sandy soil)

The estimated available Catch basin volume for stormwater retention is 20,500 cubic feet and the estimated runoff volume produced from the 100-year storm over 1 hour is 17,500 cubic feet. While both of these estimated volumes are based on some highly sensitive variables (catch basin depth, well pad porosity, and runoff coefficient), we expect that the actual retention volume will not be less than the actual runoff volume due to the conservative variable values selected for the model.

Therefore, in the event of a 100-year storm, we believe that there will be no offsite transportation of material. Smaller events will have less to no runoff, and given that vegetation

will continue to establish on the slope, GEI believes that no erosion blanket is necessary to prevent offsite migration of material prior to implementation of interim site reclamation.

REFERENCES

Piceance Creek Weather Station Data, *Weather Underground*

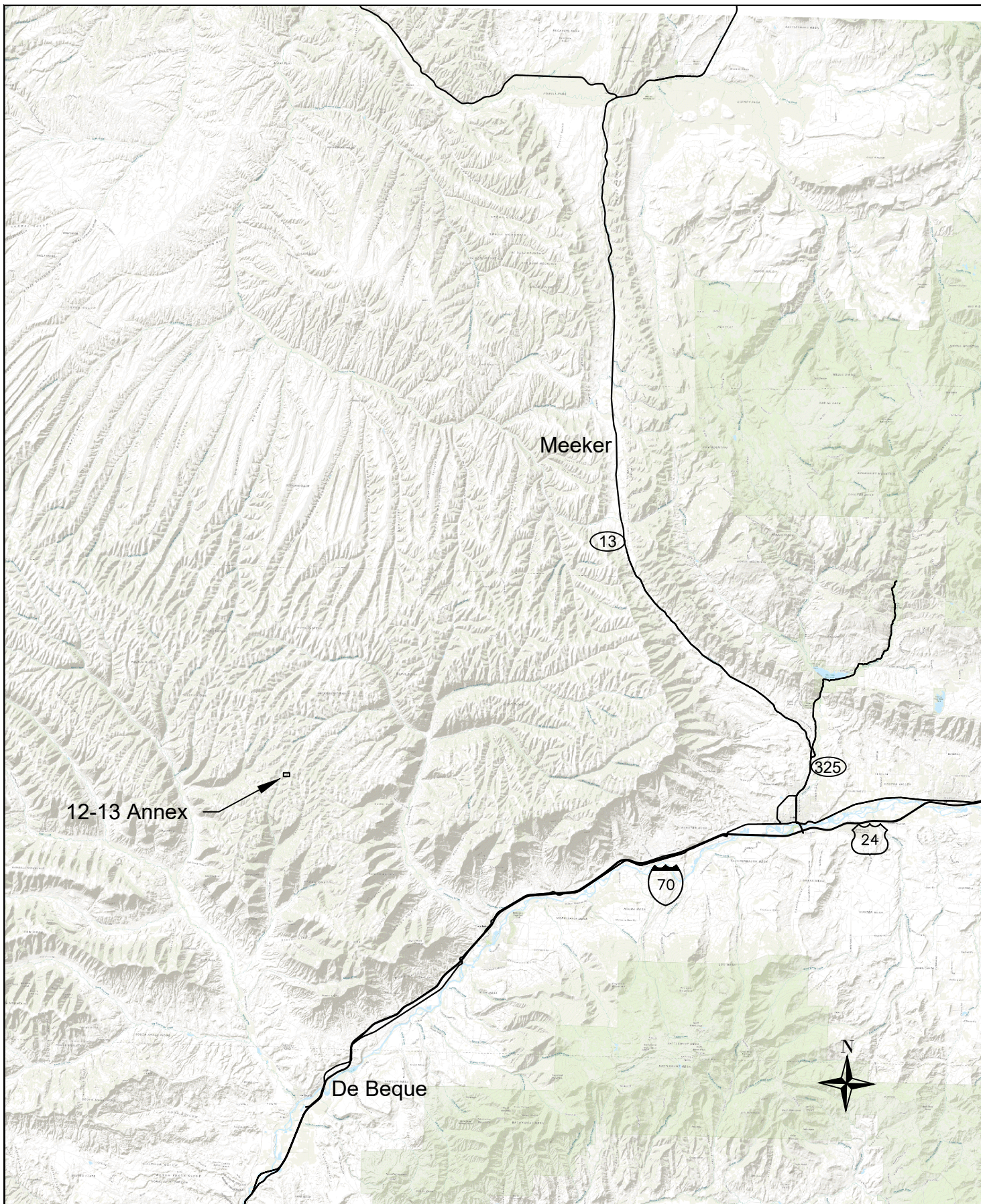
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U.S. Army Corps of Engineers (2003). Slope Stability. EM 1110-2-1902. Washington: Department of the Army, October.

U.S. Bureau of Reclamation (2011). Embankment Dams. Design Standards No. 13, Chapter 4. Department of the Interior, October.



12-13 Annex Well Pad Stability Evaluation

Garfield County, Colorado

Laramie Energy, LLC
Denver, CO

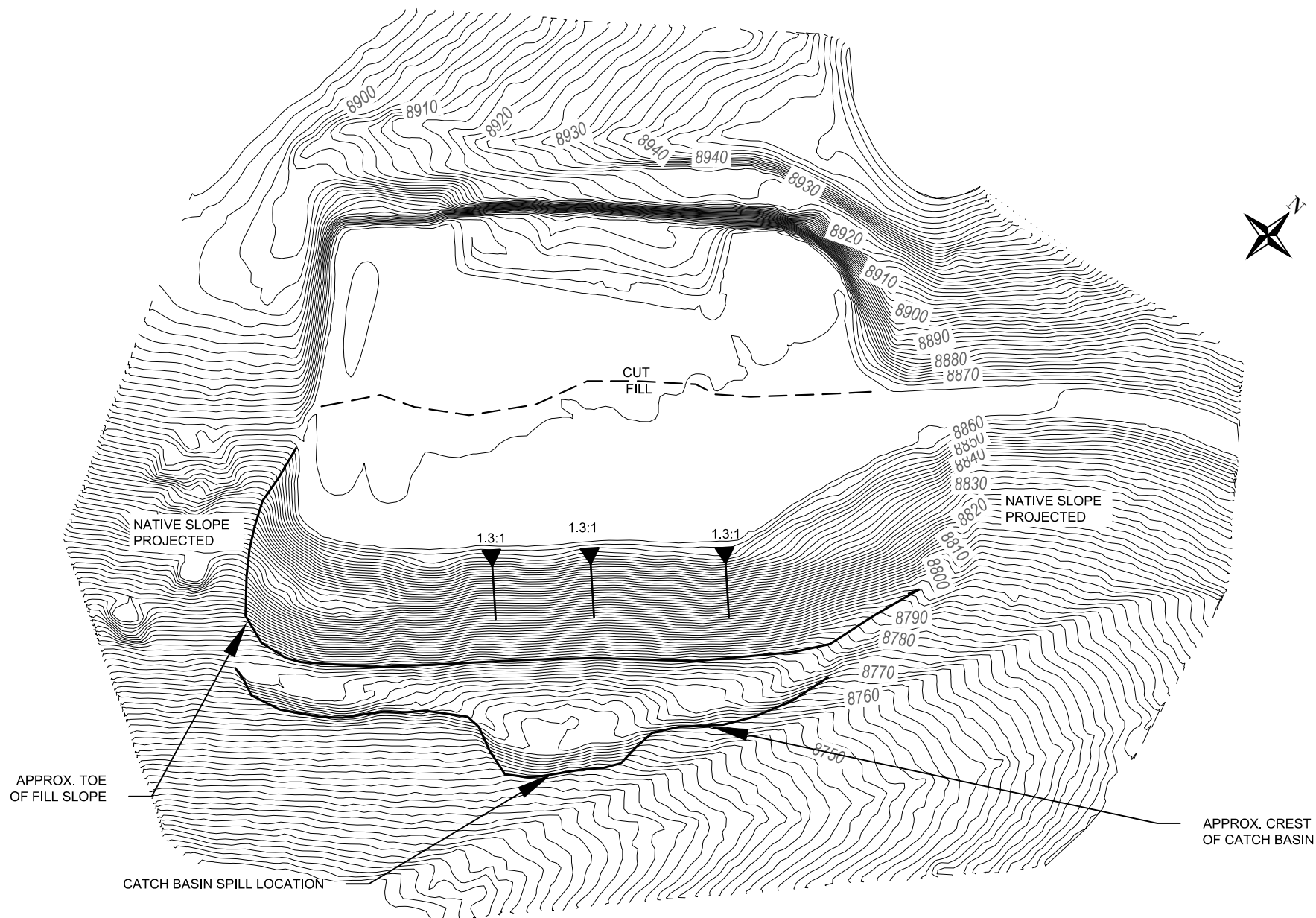


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SITE VICINITY MAP

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Fig. 1



12-13 Annex Well Pad Stability Evaluation

Garfield County, Colorado

Laramie Energy, LLC
Denver, CO

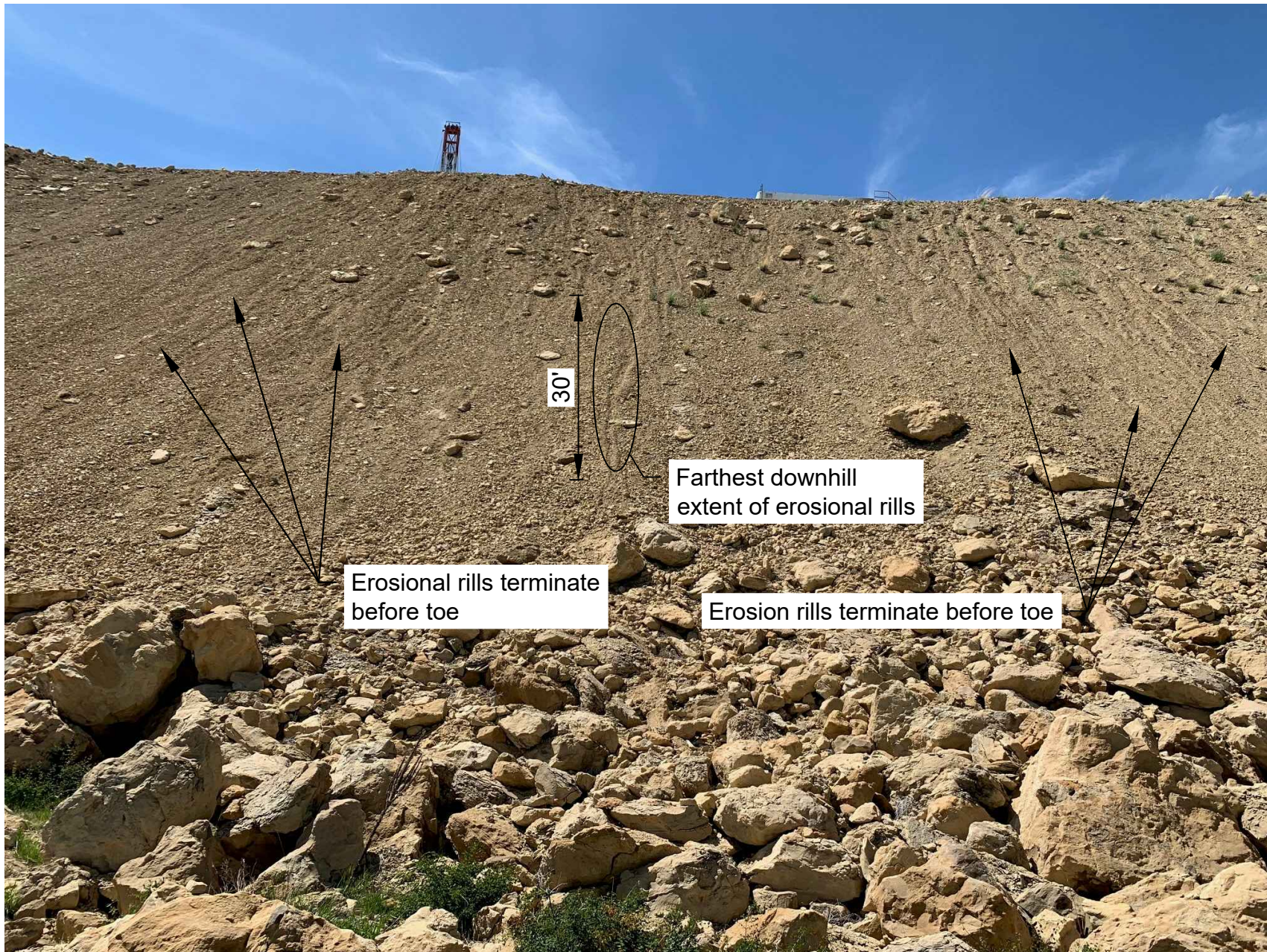


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SITE PLAN

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Fig. 2



12-13 Annex Well Pad Stability Evaluation

Garfield County, Colorado

Laramie Energy, LLC
Denver, CO



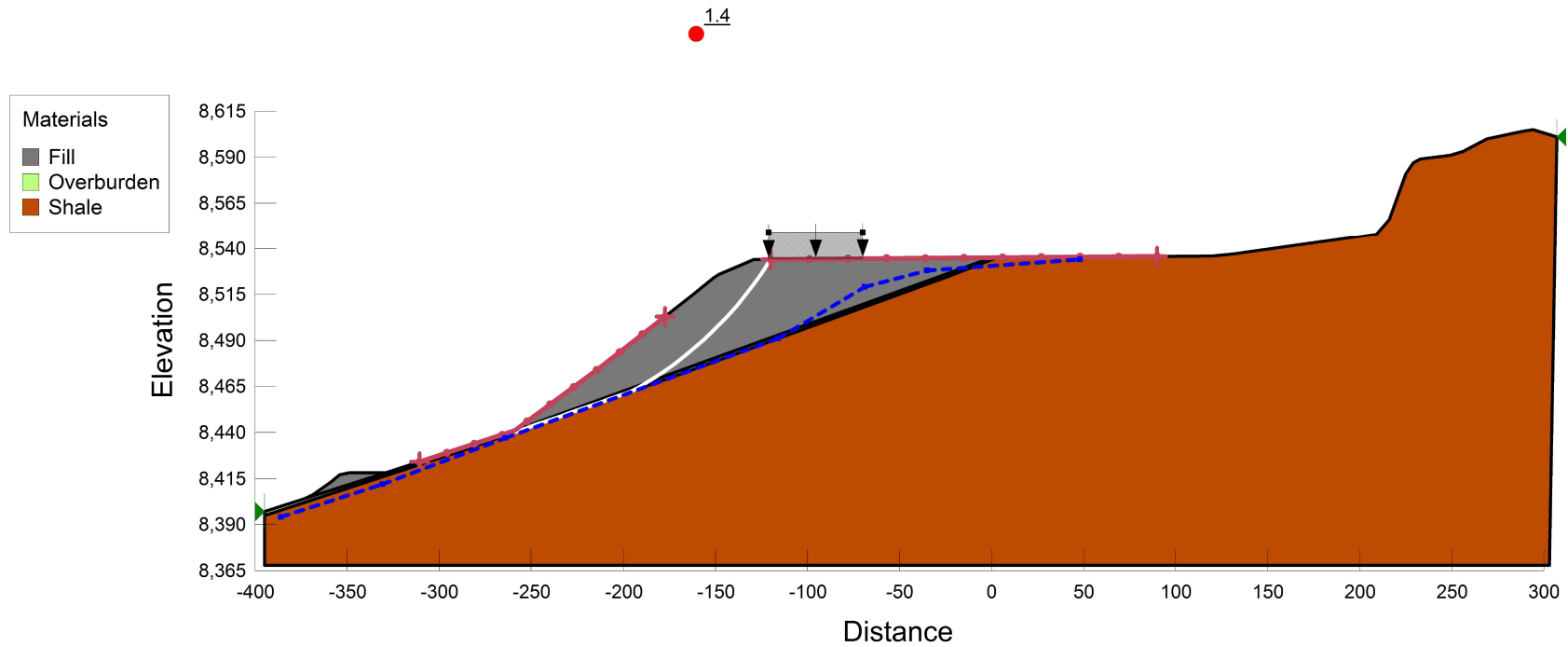
Project 1903056

NON CONTINUOUS EROSIONAL RILLS
ON 12-13 ANNEX WELL PAD

July 2019

Fig. 3

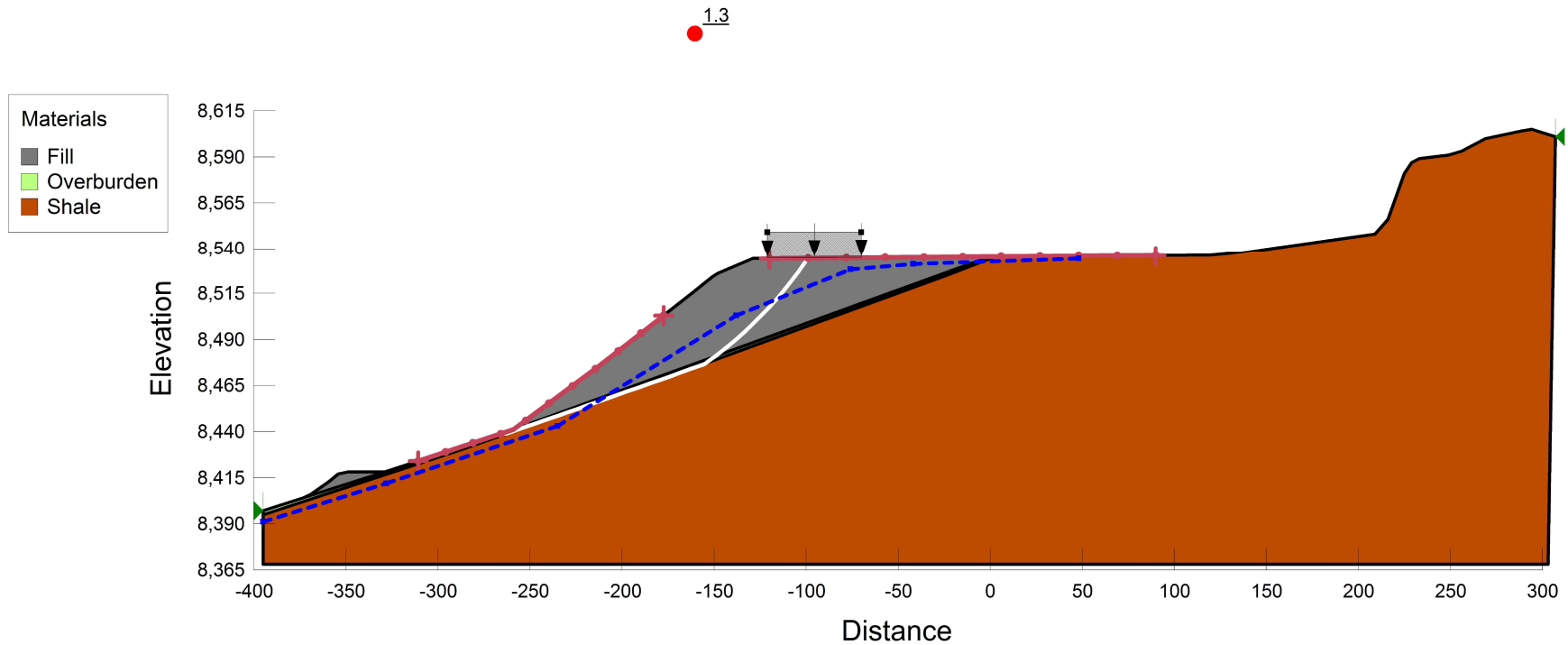
Laramie Energy 12-13 Annex - Existing



Note: Assumed groundwater conditions

<p>12-13 Annex Well Pad Stability Evaluation</p> <p>Garfield County, Colorado</p>	<p>GEI Consultants</p>	<p>EXISTING STABILITY</p>
<p>Laramie Energy, LLC Denver, CO</p>	<p>Project 1903056</p>	<p>July 2019</p> <p>Fig. 4</p>

Laramie Energy 12-13 Annex with groundwater



Note: Assumed groundwater conditions

12-13 Annex Well Pad Stability Evaluation

Garfield County, Colorado

Laramie Energy, LLC
Denver, CO



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HIGH GROUNDWATER STABILITY

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Fig. 5