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BEFORE THE ENVIRONMENTAL QUALITY COUNCIL
STATE OF WYOMING

In re Brook Mining Co., LLC coal mine permit – PT0841	))	**Docket No. 20-4802**

DEPARTMENT OF ENVIRONMENTAL QUALITY'S EXPERT WITNESS DESIGNATION

The Wyoming Department of Environmental Quality (Department), pursuant to the Council's August 18, 2020, *Scheduling Order*, hereby designates its expert witness and provides the disclosures required by Wyoming Rule of Civil Procedure 26(a)(2):

1. Mr. Daniel Overton, P.E., D.GE, President/Principal Geotechnical Engineer, Engineering Analytics, Inc., 1600 Specht Point Rd., Suite 209, Fort Collins, CO 80525.

Since June 2018, Daniel Overton has contracted with the Department's Land Quality Division to provide expert review of the subsidence-related aspects of Brook Mining Company, LLC's (Brook) permit application. Mr. Overton also reviewed public comments regarding Brook's subsidence control plan. Mr. Overton prepared four technical reports for the Department, which are attached as Exhibits 1 through 4. Mr. Overton will support his opinion testimony with these exhibits.

Mr. Overton will testify regarding the opinions he expressed in each report. This includes his conclusions regarding Brook's February 2018 Subsidence Sampling Plan, the subsidence-related portions of Brook's Round 7 and Round 8 submittals, and the subsidence-related public comments on Brook's application. In each report, Mr. Overton describes the basis and reasons for his opinions, including the facts, data, and secondary source materials that he relies upon. Among other things, Mr. Overton will testify that, as of his June 2020 report, Brook's permit application did not include an adequate subsidence control plan. He will explain that Brook's testing of a single core hole was insufficient to characterize the stratigraphy of the rock in the TR-1 highwall mining panel. Mr. Overton will also testify that Brook should conduct Atterberg Limit and consolidated-drained triaxial testing to better evaluate the long-term strength of the roof and floor materials.

Mr. Overton will testify that Conditions 9 and 10 satisfy the concerns he raised in prior technical reports. He will explain that these permit conditions can also be used to supplement Brook's subsidence control plan so that it meets all applicable requirements in the Department's Coal Rules, including the requirement that an operator's underground mining be "planned and conducted so as to prevent subsidence from causing material damage to structures, the land surface, and groundwater resources." *Rules Wyo. Dep't of Envtl. Quality, Land Quality-Coal*, ch. 7, § 2(b)(iii). It is Mr. Overton's opinion that a minimum of three core samples, their locations selected using a geostatistical algorithm, can be used to adequately represent the roof, coal, and floor materials in a future highwall mining panel. Mr. Overton believes that by using the same tests completed on core hole 2017-4, plus Atterberg Limit and consolidated-drained triaxial testing, followed by appropriate geotechnical analyses, Brook should have an adequate understanding of roof, coal, and floor strength. Mr. Overton will testify that the site-specific analysis required under Condition 9, combined with the highwall mining design that Brook already proposes, and comparison of the characteristics of future highwall mining panels with those observed for TR-1, will substantially reduce the potential for subsidence in all of Brook's future highwall mining panels. Accordingly, Mr. Overton will testify that Brook's subsidence control plan, supplemented by Conditions 9 and 10, should apply throughout the entire life of Brook's proposed highwall mining. Mr. Overton will support this opinion using facts and data from Brook's permit application.

Mr. Overton may also offer opinions to rebut expert testimony and evidence introduced by the Powder River Basin Resource Council.

Mr. Overton has over thirty-five years of professional engineering experience, with a focus on geotechnical design and mine reclamation. He has overseen technical mining projects throughout the United States, consulted with state and federal agencies on mine design, and lectured as a Faculty Affiliate at Colorado State University. Mr. Overton's full resume, which includes a complete list of his publications, is attached as Exhibit 5. In the last four years, Mr. Overton has provided testimony in only one trial or deposition, as shown in Exhibit 6. As of September 30, 2020, the Department has paid Engineering Analytics, Inc. a total of $31,571.92. This payment includes Mr. Overton's consultation fees and supporting work performed by Rob Schaut, a Senior Staff Geological Engineer. Mr. Overton's hourly billing rate is $237.00 and Mr. Schaut's is $154.00.

Dated this 20th day of October, 2020.

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CERTIFICATE OF SERVICE

I hereby certify that I served a true and correct copy of the foregoing *Expert Witness Designation* upon the persons listed below, this 20th day of October, 2020, addressed as follows:

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Technical Memorandum

To:	Mr. B.J. Kristiansen, P.G.	From:	Daniel D. Overton, P.E.
Company:	Wyoming Department of Environmental Quality – Land Quality Division	Date:	June 29, 2018
EA No.:	110875		Professional Engineer (Civil) DANIEL D. OVERTON 8209 Date 6/29/2018 WYOMING
Re:	Review of Brook Mine Subsidence Sampling and Analysis Plan		

1.0 INTRODUCTION

Engineering Analytics, Inc. (EA) was tasked by the Wyoming Department of Environmental Quality (DEQ) Land Quality Division (LQD) to provide an evaluation of a subsidence sampling and analysis plan submitted by the Brook Mine. The Brook Mine is a sub-bituminous coal mine located approximately 8 miles north of the City of Sheridan in Sheridan County, Wyoming.

On September 28, 2017, the State of Wyoming Environmental Quality Council (EQC) issued the *Findings of Fact, Conclusions of Law, and Order* (Order) regarding Docket 17-4802, In Re Brook Mine Application (TFN 6 2-025). On February 3, 2018, RAMACO submitted to DEQ the "*2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order*" (the Plan) prepared for RAMACO by WWC Engineering. The Plan was prepared in response to a DEQ letter to the Brook Mine dated January 18, 2018, requesting Brook to submit their plan to address the subsidence issues raised by the EQC Order.

This Technical Memorandum provides an evaluation of the Brook Mine's subsidence sampling and analysis plan, and the adequacy of addressing each subsidence finding in the EQC Order; as well as recommendations for alternative approaches to address the subsidence-related EQC findings.

2.0 SUBSIDENCE-RELATED FINDINGS OF THE ENVIRONMENTAL QUALITY COUNCIL ORDER

A review of the EQC Order Section V. Findings of Fact (Findings) indicates the items relevant to subsidence include: Findings No. 50 through No. 61, (pages 16 and 17). Each of the subsidence-related Findings is listed below.

50. There have been inadequate studies and testing done to draw any scientific conclusions as to the long-term risk of subsidence at the permit area. *Transcript – Marino testimony, pp. 1200, 1246.*

Exhibit 1

51. The deficiencies and lack of a subsidence plan were explained by Dr. Marino

52. The permit application does not provide sufficient information to provide a meaningful review with respect to subsidence potential. *Transcript – Marino testimony, pp 1237, 1284-85*

53. Appropriate data was not collected to do a site-specific assessment of the strength and stability of the roof, floor, and pillar materials at the permit area. *Transcript – Marino testimony, pp. 1211, 1228-122.*

54. The subsidence control plan exhibits a lack of geomechanical understanding of the long-term and short-term stability of the mine. *Transcript – Marino testimony, p. 1228.*

55. There is insufficient information or data in the permit application and very limited analysis of subsidence risk in the documents such that the subsidence potential cannot be assessed. *Transcript – Marino testimony, p. 1228.*

56. The calculation in the mine plan improperly used coal strength data for bituminous coal rather than the sub-bituminous coal which exists at the site. *Transcript – Marino testimony, pp. 1226-1227, 1234, 1247.*

57. Complete subsidence control plans are typically stamped by a professional engineer and such plan is part of the permit application. *Transcript – Marino testimony, pp. 1238-1239.*

58. The mine plan is not complete due to the lack of proper testing and analysis to determine the risk of subsidence due to mining activities. *Transcript – Marino testimony, p. 1244.*

59. Brook admitted that the studies and work suggested by Dr. Marino are necessary steps for a proper mine subsidence plan. *Transcript – Barron testimony, pp. 674-675.* However, Brook did not perform those studies or work as part of its subsidence control plan. *Transcript – Barron testimony, pp. 1532-33.* Brook chose not to perform the necessary engineering work in the permit application for permitting efficiency purposes. *Transcript- Barron testimony, pp. 1532 -1535.*

60. Brook plans to do the necessary engineering work Dr. Marino suggests as part of the ground control plan. Transcript – Barron testimony, pp. 1532-1533.

61. The risk of subsidence and subsidence control have not yet properly been studied or assessed.

The subsidence-related Findings Nos. 50 though 61 generally state there is:

- A lack of information, inadequate studies and data collection, and lack of testing and analysis to date for a site-specific evaluation of strength of ground conditions (e.g., sampling and analysis plan). (Findings No. 50, 53, 55, 56, 58, and 59)
- A need for an understanding of short-term and long-term stability (e.g., stability analysis), and the lack of an evaluation for the potential risk for subsidence (e.g., understand failure mechanisms and risk), and resultant extent of subsidence. (Findings No. 50, 52, 53, 54, 55, and 56)
- The need for an approach, or plan to mitigate subsidence, via a subsidence control plan, or a ground control plan (as a part of the mine plan). (Findings Nos. 51, 57, 60, and 61)
- A commitment by the Brook Mine to do the appropriate studies per Dr. Marino's suggestions to move towards a proper mine subsidence plan. (Findings No. 59 and 60)

3.0 REVIEW OF SAMPLING AND ANALYSIS PLAN

The Plan submitted to DEQ in February 2018 consists of three sections: an Introduction (Section 1.0), Hydrologic Monitoring (Section 2.0), and Subsidence Sampling Plan (Section 3.0). The focus of this subsidence evaluation is Section 3.0.

The narrative presented in the Subsidence Sampling Plan is summarized as follows:

- Coring will be conducted at two locations to obtain samples for subsidence materials testing.
- Strength testing will be performed on roof, coal, and underburden core samples for the first highwall panels proposed for years 6 through 10; strength testing on future panels will occur prior to mining.
- Two 2-inch piezometers will be installed in the Carney overburden (578415-OVB-1 and 578415-OVB-2) following coring to characterize overburden saturation, even if the overburden produces water.
- Procedures are provided for drilling a pilot hole for geophysical logging, then coring approximately 20 feet from the pilot hole to retrieve core; then completion of boreholes with screened intervals based on the geophysical logging, and installation of piezometers.

Based on review of the Subsidence Sampling Plan (Section 3.0 of the Plan), it appears drilling and coring at two locations is intended to be multi-purpose; for subsidence materials testing and for hydrologic monitoring. From piezometer locations presented on Exhibit 2 – Ground Water and Surface Water Monitoring (578415-OVB-1 and 578415-OVB-2), these boreholes are within the northwest quarter of Section 15, although the text does not reference Exhibit 2. It is unclear from the text description and Exhibit 2, the relevance of these two core locations to the proposed highwall panels, or mining location (proposed for years 6 through 10). In addition, given the extent of mining, no discussion is provided to justify testing rock from only two borehole locations, and not a larger geological area.

In regards to sampling, the narrative lacks specificity for core drilling and logging, collection of core for sampling, and strength testing. The text states strength testing will be performed on roof, coal and underburden core samples from two locations. However, estimated depths of drilling and stratigraphic intervals are not provided, nor number and volume of core samples to be retrieved from each zone within each borehole. The procedures described do not include specificity for documentation of rock structure and characteristics, logging, and recording the rock quality designation (RQD). The text indicates that strength testing will be performed but details for the various rock mechanics tests are not provided (e.g., tensile strength, uniaxial compression or point load strength, or consolidated-drainage triaxial strength) and specific ASTM standards are not referenced.

Overall, the Subsidence Sampling Plan commits to two locations for coring and piezometer installation. However, details for sampling and analysis for rock strength testing and analysis are not presented. Therefore, the text does not present a full understanding for the intent of data collection for strength testing, and how the data will be analyzed to technically evaluate the rock stability, and subsequent subsidence prediction due to planned mining.

4.0 ALTERNATIVE APPROACHES TO ADDRESS SUBSIDENCE-SPECIFIC FINDINGS

The Subsidence Sampling Plan (Section 3.0 of the Plan) indicates it "*is meant to address Findings No. 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, and 61 of the Order*". In terms of the Subsidence Sampling Plan adequately addressing each subsidence-related Finding listed above from the EQC Order, two points can be made. One point is overall, none of the Findings have been fully addressed by the Subsidence Sampling Plan. However, the second point is the Brook Mine committed to do the appropriate studies (Finding No. 60), and the Subsidence Sampling Plan shows intent to begin preliminary work, although it is not sufficient as presented.

Each of the EQC Findings related to subsidence were reviewed followed by a review of the Subsidence Sampling Plan. These Findings were summarized above and can generally be are grouped into three categories that are required for the Brook Mine: data collection, testing, and analysis; stability analysis and subsidence prediction; and a subsidence control plan.

Some possible alternatives to address the Findings listed above would be to consider the following approach, with participation of a professional engineer experienced with mine subsidence.

- Data Collection, Testing and Analysis – A sampling and analysis plan needs to be developed to collect appropriate core data from representative geological structures of the proposed mine area. The core requires testing by a geotechnical lab to collect strength parameters necessary for stability analysis and subsidence prediction. All work needs to follow the industry accepted ASTM standards.
- Stability Analysis and Subsidence Prediction – Following acceptance of reviewed geotechnical test data, stability analysis should be performed to understand the areas that may be impacted by subsidence (e.g., pillar failure analysis, roof entry analysis, roof/floor bearing analysis). Consideration should be made for geological features (e.g., faults), as well as the hydrologic conditions and how these may influence stability and the potential for subsidence. These analyses will allow for the development of subsidence prediction for the planned mining.
- Subsidence Control Plan – Upon completion of stability analysis and subsidence prediction for the planned mining, a subsidence, or ground control plan should be developed to mitigate potential impacts.

The EQC Findings note that the Brook Mine permit application was deficient in the areas of hydrology, subsidence, and blasting plan (Finding No. 96). In addition the EQC Findings note that the subsidence control plan concludes there will be no subsidence, but the EQC disagrees with the conclusion (Finding No. 98), and deemed the Brook Mine permit application deficient.

In regards to subsidence, it is our opinion that the proposed investigation, testing, analyses, subsidence prediction and subsidence control plan remains deficient. We recommend that a work plan be developed detailing the three-phase approach identified above to assist in advancement of the understanding of the site conditions, the potential for subsidence, and the approach for subsidence control.

5.0 REFERENCES

State of Wyoming Environmental Quality Council, 2017. Findings of Fact, Conclusions of Law, and Order, Docket 17-4802, In RE Brook Mine Application, TFN 6 2-025, filed September 28, 2017.

WWC Engineering, 2018. 2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order, prepared for: RAMACO, prepared by: WWC Engineering.

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Technical Memorandum

To:	Mr. B.J. Kristiansen, P.G.	From:	Daniel D. Overton, P.E.
Company:	Wyoming Department of Environmental Quality – Land Quality Division	Date:	January 14, 2019
EA No.:	110875		Professional Engineer (Civil) DANIEL D. OVERTON 8209 Date 1/14/2019 WYOMING
Re:	Review of Brook Mine Permit to Mine Application Specific to Subsidence: Response to EQC Finding of Facts and Conclusions of Law, WDEQ Comments Round 7, and Supplemental Materials.		

1.0 INTRODUCTION

Engineering Analytics, Inc. (EA) was tasked by the Wyoming Department of Environmental Quality (DEQ) Land Quality Division (LQD) to provide an evaluation of subsidence-related documentation regarding the Brook Mine Permit to Mine Application (TFN 6 2/025). The specific documentation is included in *Response to EQC Finding of Facts and Conclusions of Law, WDEQ Comments Round 7* (Round 7 Submittal) submitted by WWC Engineering on behalf of RAMACO Wyoming Coal, LLC to DEQ, on October 29, 2018. The Round 7 Submittal includes responses to specific subsidence-related comments and also references supplemental materials provided as part of the Mine Plan.

The Brook Mine is a sub-bituminous coal mine located approximately 8 miles north of the City of Sheridan in Sheridan County, Wyoming. On September 27, 2017, the State of Wyoming Environmental Quality Council (EQC) issued *Findings of Fact, Conclusions of Law, and Order (Order) regarding Docket 17-4802, In Re Brook Mine Application (TFN 6 2-025)* (Order).

On February 3, 2018, RAMACO submitted to DEQ the "*2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order*" (Subsidence SAP) prepared for RAMACO by WWC Engineering. The Subsidence SAP was prepared in response to a DEQ letter to the Brook Mine dated January 18, 2018, requesting the Brook Mine to submit a plan to address the subsidence issues raised by the EQC Order. On behalf of the DEQ, EA provided comments in a memorandum (EA SAP Review Memo) dated June 29, 2018, regarding the Subsidence SAP submitted by the Brook Mine and how it addressed the findings of the September 27, 2017 Order.

This Technical Memorandum provides an evaluation of the subsidence-related comments in the Brook Mine's Round 7 Submittal, including the subsidence-related Findings No. 50 through No. 61, and the supplemental materials referenced, including:

- Mine Plan Addendum MP-6 Subsidence Control Plan dated July 30, 2015; and
- Attachment MP-6-A *Geotechnical Design and Operational Considerations for Highwall Mining – Brook Mine*, by Agapito Assoicates, Inc. dated September 13, 2018.

Exhibit 2

Agapito Associates, Inc. was contracted by Ramaco Carbon, LLC (Ramaco) to evaluate highwall mining for the Brook Mine. This Agapito Report was specific to the TR-1 area in Section 15 of T57N, R84W (Exhibit MP.4-1). The mining will consist of a box cut mined to expose the Carney Seam to develop the highwall mining.

2.0 SUBSIDENCE-RELATED FINDINGS AND ROUND 7 SUBMITTAL RESPONSES

A review of the EQC Order Section V. Findings of Fact (Findings) indicates the items relevant to subsidence include: Findings No. 50 through No. 61, (pages 16 and 17). Each of the subsidence-related Findings is listed below.

50. There have been inadequate studies and testing done to draw any scientific conclusions as to the long-term risk of subsidence at the permit area. *Transcript – Marino testimony, pp. 1200, 1246.*

51. The deficiencies and lack of a subsidence plan were explained by Dr. Marino.

52. The permit application does not provide sufficient information to provide a meaningful review with respect to subsidence potential. *Transcript – Marino testimony, pp 1237, 1284-85*

53. Appropriate data was not collected to do a site-specific assessment of the strength and stability of the roof, floor, and pillar materials at the permit area. *Transcript – Marino testimony, pp. 1211, 1228-122.*

54. The subsidence control plan exhibits a lack of geomechanical understanding of the long-term and short-term stability of the mine. *Transcript – Marino testimony, p. 1228.*

55. There is insufficient information or data in the permit application and very limited analysis of subsidence risk in the documents such that the subsidence potential cannot be assessed. *Transcript – Marino testimony, p. 1228.*

56. The calculation in the mine plan improperly used coal strength data for bituminous coal rather than the sub-bituminous coal which exists at the site. *Transcript – Marino testimony, pp. 1226-1227, 1234, 1247.*

57. Complete subsidence control plans are typically stamped by a professional engineer and such plan is part of the permit application. *Transcript – Marino testimony, pp. 1238-1239.*

58. The mine plan is not complete due to the lack of proper testing and analysis to determine the risk of subsidence due to mining activities. *Transcript – Marino testimony, p. 1244.*

59. Brook admitted that the studies and work suggested by Dr. Marino are necessary steps for a proper mine subsidence plan. *Transcript – Barron testimony, pp. 674-675.* However, Brook did not perform those studies or work as part of its subsidence control plan. *Transcript – Barron testimony, pp. 1532-33.* Brook chose not to perform the necessary engineering work in the permit application for permitting efficiency purposes. *Transcript- Barron testimony, pp. 1532 -1535.*

60. Brook plans to do the necessary engineering work Dr. Marino suggests as part of the ground control plan. Transcript – Barron testimony, pp. 1532-1533.

61. The risk of subsidence and subsidence control have not yet properly been studied or assessed.

The Round 7 Submittal responses related to subsidence are the EQC Findings No. 50 through No. 61 as follows:

Response EQC 50 – Round 7

> *Brook Mine selected Agapito Associates, Inc. of Colorado to prepare the geotechnical design of the TR-1 highwall mine area. The report that they prepared is included in Mine Plan Addendum MP-6. This report includes an evaluation of the potential subsidence for the proposed mining area.*
>
> *The highwall mining plan for the Brook Mine has been developed to minimize the likelihood of trough subsidence.*

Response EQC 53 – Round 7

> *Please see response to Comment 50. The site specific test program includes:*
>
> > *Uniaxial compression tests (UCS) with elastic properties (Young's modulus (E) and Poisson's ratio (ν)), axial and diametral point load tests (PLT), and slake durability tests.*

Response EQC 60 – Round 7

> *Brook contracted Agapito Associates, Inc. to prepare highwall report for the TR-1 in Section 15 of T57N, R84W (Exhibit MP.4-1). This report can be found in Mine Plan Addendum MP-6.*

Response EQC 51-52, 54 – 59, and 61 – Round 7

> *Please see response to Comment 50.*

3.0 REVIEW OF THE MINE PLAN ADDENDUM MP-6

3.1 Attachment MP-6 – Subsidence Control Plan

The Subsidence Control Plan, dated July 2015 provides a highwall mining plan, a review of previous mining activity, subsidence monitoring and assessment, and subsidence control and remediation. The highwall mining plan (Section MP-6.1) indicates use of an ADDCAR highwall mining system with the capability to cut an 11.0-foot wide opening and a maximum height of 15.1 feet. The plan includes a hole penetration depth of 2000 feet. The plan discussed highwall mining of two spilts of the Carney seam and one thicker Carney seam and support pillars with a width equal to or exceeding the maximum extraction thickness, at least 1:1, providing conformance with the National Institute for Occupational Safety and Health (NIOSH) ARMPS-HWM stability program.

The review of the previous mining activity (Section MP-6.2) in the area includes maps from the Sheridan Wyoming Coal Company Mine No. 44 and review of aerial imagery, indicating chimney subsidence. The chimney subsidence occurred in the southwestern portion of the historic mine, in areas that indicate panel rooms of 20 feet in width, with connecting mains and submains of 15 feet in width, and connecting crosscuts of 10 feet or less in width. The subsidence appeared in areas of overburden cover depth of less than 120 to 150 feet. Calculations using the Dyne equation (1998) indicate that chimney subsidence may occur with these types of spans (20 to 25 feet) in the 16-foot high Carney seam, at 150 feet in height. Therefore, the Brook Mine plan proposed highwall mining opening width of 11 to 11.5 feet. The plan concludes that surface subsidence should not occur due to the guidance system for straight hole alignment, the conservative pillar wide, pillar stacking for multiple-seam mining, and narrow entries.

The subsidence monitoring and assessment (Section MP-6.3) provides for initial assessment of the ground surface six months prior to monitoring, as well as visual monitoring on a monthly basis, and six months following completion of mining. In addition, stream profiles will be developed and surveyed semi-annually. Subsidence control and remediation (Section MP-6.4) would follow the Reclamation Plan for seeding, after appropriate restoration is made for the by backfilling and self-healing.

As presented in the discussion below, the Agapito Report furthers the subsidence analysis from the Subsidence Control Plan for the Brook Mine. The Agapito Report includes some of the similar design components of the narrow opening width of 11.5 feet, but does not include multiple seam mining, only mining of the thicker Carney seam. The analysis in the Subsidence Control Plan of the nearby Mine No. 44 is noteworthy as it provides useful information that is considered in the Agapito Report in the subsidence evaluation (Section 6.1).

3.2 Attachment MP-6A – Geotechnical Design and Operational Considerations for Highwall Mining – Brook Mine (Agapito Report)

The Agapito Report, as stated above, focuses on site characterization, engineering design, and operational considerations. The Agapito Report includes a review of mine area specific core, observations and geotechnical testing of the core (Section 2). Analyses was performed for the highwall mining for opening dimensions, including evaluation of the roof and floor stability, and with regards to protection of surface structures (Section 3). Pillar design under various depths of over and at various mining heights was evaluated, and with various recoverable volumes (Section 4). To confirm the approach to mining, numerical modeling was performed using standard practice methodologies of LaModel Analysis and UDEC Analysis (Section 5). Finally, a subsidence evaluation is presented, and recommendations are made for operations (Section 6).

The site geology and mining setting are described in the Section 2 site characterization, including reference to the nearby Acme 2 Mine that mined the Carney Seam with 25-feet wide rooms. Testing of core from 2017-4, a recent geotechnical core hole provided physical properties for analyses include UCS, E, Poisson's ratio, Slake, PLCS, PCT-D, density, and moisture. Core observations indicate a profile of sandstone, mudstone, coal and carbonaceous mudstone. The Agapito Report indicates the results of the strength characteristic data of the Carney seam is found to be similar to those at surface mines in the western U.S. However, the report states the coal-bounding strata are indicated to be similar, although are marginally weaker than those found at western strip operations. The appendices provide the core logs and rock mechanics testing (uniaxial compressive strength test data and plots, point load data, and slake durability data).

The highwall mining geometry is presented in Section 3. The mining opening dimensions are presented for an ADDCAR Systems, LLC highwall mining system with consideration of the coal thickness ranging from 14 to 16 feet. As the dip of the seam is shallow, during mining the mining height will not be reduced more than 0.5 feet. Protection of surface structures is presented with a recommendation of establishment of a buffer with a fixed offset of 50 feet and an angle of critical deformation of 25 degrees. Regarding roof stability, rock mass rating (RMR) and Q values were calculated from the core, site conditions, and engineering judgment. A stand-up time is estimated at 77 days, and it is recommended to leave 6 to 12 inches of top coal to improve roof conditions and reduce dilution. Regarding floor stability, the coal seam is underlain by a thin layer of weak carbonaceous mudstone that may affect pillar and floor stability. Therefore, it is proposed to leave a 1-foot thick coal layer on the floor to provide additional stability.

The design includes both an empirical pillar design and numerical modeling to confirm the design performance following standard industry practice, including the Mark-Bieniawski formula, and the LaModel and UDEC models, respectively. The empirical design results presented in Section 4 show web pillar design and barrier pillar design charts for the 1.6 stability factor, as well as recoverable resources. A proposed panel layout is presented based on the parameters of a 14 ft mining height, 90% of the maximum cover depth, and average penetration depths. An appendix is included with alternate design charts for the 1.8 stability factor.

The numerical models presented in Section 5 are based on the deepest cover of 373 feet, and a 14 ft mining height with an 18.3-ft web pillar and 58.1-ft barrier pillar, based on the 1.6 stability factor. The LaModel numerical modeling method checked the web and barrier pillar design and the design for cascading pillar failure potential. The report indicates the vertical stresses agree with the expected 619 psi average pillar stress under the deepest cover depth, or design depth. In addition, the analyses indicate the design is not prone to cascading failure, even in the case of a complete failure of an entire pillar. The UDEC modeling analyses was performed to confirm the empirical and LaModel results, check roof and floor stability and other potential failure mechanisms. Overall the results from both models indicate the roof and floor will remain stable, however, the report indicates the roof is predicted to be weak.

An evaluation for subsidence is presented in Section 6 along with operational considerations. The following summarizes this section:

- Regarding trough subsidence, the highwall mining plan has been designed to minimize trough subsidence based on the substantial pillar size, 1:1 width to height pillar ratio, reduced in-situ coal strength for the Carney seam, LaModel modeling results demonstrate cascading failure is unlikely, and use of 1.6 and 1.8 stability factors.
- Sinkhole subsidence has been evaluated and the risk is considered to be low, although should still be recognized as a possibility in the area of the shallow cover areas near the box cut. Various studies note the possibility of sinkhole subsidence at mines with shallow cover, including the Mine No. 44 near the Brook Mine at cover depths less than 140 feet.
- The Matheson equation is used, using a model from a Colorado Springs Mine, by accounting for a thicker coal seam at the Brook Mine, to evaluate probability of a collapse reaching the surface. The estimate concludes that 5 sinkholes may develop in shallow cover less than 140 feet in depth.
- Another analysis using the Mine No. 44 sinkhole data, with openings of 25-feet wide, indicated that in the 86 acre development section of the Brook mine ranging between 140 to 150 foot depth of cover, the sinkhole frequency is 0.19 holes/acre.
- Overall the evaluation indicates the Brook Mine is less susceptible to subsidence than historic mines, with narrow opening (11.5 feet compared to 25 feet), development only mining as opposed to retreat mining that allows for collapse, no intersections or crosscuts, and a lower extraction ratio (39% compared to 50%).

4.0 REVIEW OF WYOMING ADMINISTRATIVE CODE

A review of the Department of Environmental Quality (020) regulations related to Land Quality – Coal (0006) of the Wyoming Administrative Code (WAC) were reviewed in regards to subsidence for underground coal mining. Pertinent sections with citations relevant to subsidence include:

- Chapter 1: Authorities and Definitions for Surface Coal Mining Operations (020.0006.1.08272014)
- Chapter 2: Permit Application Requirements (020.0006.2.08272014)
- Chapter 4: Environmental Protection Performance Standards (020.0006.4.12172012)
- Chapter 7: Underground Coal Mining (020.0006.7.04112011)

In general, the Subsidence Control Plan and the Agapito Report appear to provide information requested by the code related to evaluating for the potential of subsidence for the planned underground coal mine. The documents provide geotechnical analyses based on local core, with standard approaches to design for stability with the intent to minimize subsidence, as well as provide for monitoring and remediation in the event of subsidence.

5.0 COMMENTS

The Agapito Report furthers the approach for a geotechnical sound design and stability analysis for the Brook Mine plan and it follows the standard approach for geotechnical design of a highwall mine as confirmed by literature (e.g., Mo et al., 2016; Ross et al., 2018; Zipf, 2005). The design is based on test results from site-specific core and provides conservatism with 1.6 and 1.8 safety factors. The Executive Summary presents a list of issues and concerns and provides findings and recommendations based on the geotechnical evaluation within the report. The issues and concerns address the overall stability of the mine plan and potential for surface subsidence. The findings indicate that there may be roof falls over time in the highwall mining openings. However, the propagation of the falls to the surface are considered unlikely, and therefore, the design is not prone to development of trough or sinkhole subsidence features. Evaluation of subsidence using existing data and historic local information demonstrates the Brook Mine will be less susceptible to subsidence than historic mines. Of note is the subsidence evaluation in both the Subsidence Control Plan and in the Agapito Report, and the consideration of the historic local subsidence of the Mine No. 44, in close proximity to the Brook Mine TR-1 panel. Regarding regulatory requirements, the Wyoming Administrative Code was reviewed in terms of subsidence requirements in Chapters 1, 2, 4, and 7 and it appears the intent of both the Subsidence Control Plan and the Agapito Report provide the information required by the code.

Specific comments are submitted that include the following:

1. In the EA SAP Review Memo a comment was made in regards to the Subsidence SAP, Section 3.0. stating:

   "Based on review of the Subsidence Sampling Plan (Section 3.0 of the Plan), it appears drilling and coring at two locations is intended to be multi-purpose; for subsidence materials testing and for hydrologic monitoring. From piezometer locations presented on Exhibit 2 – Ground Water and Surface Water Monitoring (578415-OVB-1 and 578415-OVB-2), these boreholes are within the northwest quarter of Section 15, although the text does not reference Exhibit 2. It is unclear from the text description and Exhibit 2, the relevance of these two core locations to the proposed highwall panels, or mining location (proposed for years 6 through 10). In addition, given the extent of mining, no discussion is provided to justify testing rock from only two borehole locations, and not a larger geological area."

Based on the Subsidence SAP, coring was to be conducted at two locations to obtain samples for subsidence materials testing. In addition, the Subsidence SAP states that strength testing will be performed on roof, coal, and underburden core samples for the first highwall panels proposed for years 6 through 10, with strength testing on future panels occurring prior to mining.

It is understood that the core evaluated in the Agapito Report was identified as 2017-4. The borehole location is not noted in the Subsidence Control Plan or the Agapito Report. However, EA received the coordinates from WDEQ of Lat: 44.919101, LON: 106.985681; and N: 1,938,754, E: 1,402,386; and confirmed the location is within Panel 1 depicted on Figure 10 of the Agapito Report.

There does not appear to be a discussion in the Subsidence Control Plan or in the Agapito Report for an additional borehole core testing as indicated in the Subsidence SAP, or for demonstration of how much geotechnical testing is suitable. The applicant should indicate whether there are plans for an additional borehole analyses for this panel and how will physical characterization be performed for the additional panels in the mine plan and for potential subsidence.

2. The Subsidence Control Plan provides for monitoring, and in the event of subsidence, provides plans for reclamation. The applicant should indicate the plan, or best practices implemented to perform subsidence evaluations in the event of unexpected subsidence.

3. In regards to the slake durability test discussion, Section 2.2.1 of the Agapito Report states:

   "Poor floor conditions are likely to be encountered within the highwall miner opening; therefore, AAI recommends leaving 6 to 12 inches of floor coal, which should improve trafficability."

   In regards to the roof stability analysis, Section 3.3 of the Agapito Report states:

   "If roof competence proves to be an issue during mining, leaving 6 to 12 inches of top coal should improve roof conditions and reduce dilution".

   In the Operational Considerations, Section 6.2 of the Agapito Report states:

   "The calculated stand-up times for the roofs of all HWM areas indicates that the roofs should be sufficiently stable to allow highwall mining. However, the rocks types are generally classified as weak (CMRR) and occasional roof falls may occur. AAI recommends leaving a 1-ft thick layer of top coal to reduce weathering of the CMS layer and improve stability". If mining exposes the CMS layer in the floor, trafficability problems are considered likely; therefore, AAI recommend leaving a 1-ft-thick layer of floor coal to improve conditions."

   And the Executive Summary of the Agapito Report states in the 3rd bullet:

   "Marginal roof stability and floor trafficability is likely to be encountered; therefore, AAI recommends leaving roof and floor coal to mitigate these issues."

   The recommendations for the thickness of leaving coal on both the roof and the floor appear to vary and suggest dependency upon the materials encountered in the floor. Given the overall Carney seam thickness is approximately 16 feet, an allowance for leaving coal on both the floor and roof seems feasible for the design. The applicant should make a specific recommendation for the thickness of coal to be left on the roof and the floor.

6.0 REFERENCES

Agapito Associates, Inc., 2018. Attachment MP-6-A Geotechnical Design and Operational Considerations for Highwall Mining- Brook Mine, prepared for RAMACO Carbon, September 13, 2018, 117 p.

Mo, Sungsoon, Dhengguo Zhang, Ismet Canbulat, Paul Hagan (2016). A Review of Highwall Mining Experience and Practice, in Naj Azis and Bob Kininmonth (eds), Proceedings of the 16th Coal Operators' Conference, Mining Engineering, Univeristy of Wollongong, 10-12 February 2016, 522-530.

RAMACO, 2018. Addendum MP-6 Subsidence Control Plan, Brook Mine Permit Application, Volume XI, Mine Plan, October 28, 2018.

Ross, Chris, David Conover, and Jake Baine (2018). Highwall mining of thick, steeply dipping coal – a case study in geotechnical design and recovery optimization, International Journal of Mining Science Technology, http://doe.org/10.1016/j.ijmst.2017.12.022.

State of Wyoming Environmental Quality Council, 2017. Findings of Fact, Conclusions of Law, and Order, Docket 17-4802, In RE Brook Mine Application, TFN 6 2-025, filed September 28, 2017.

WWC Engineering, 2018a. 2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order, prepared for: RAMACO, prepared by: WWC Engineering, January 18, 2018.

WWC Engineering, 2018b. Response to EQC Finding of Facts and Conclusions of Law, WDEQ Comments Round 7, Brook Mine Permit to Mine Application, TFN 6 2/025, prepared by WWC Engineering, submitted to Wyoming Department of Environmental Quality, October 19, 2018.

Wyoming Administrative Code, 2018. Wyoming Administrative Code, Department of Environmental Quality, Land Quality – Coal (0006).

Zipf, R. K. (2005). Ground Control Design for Highwall Mining, SME Annual Meeting, pre-print number 05-82, 2005, 9 pp.

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Technical Memorandum

To:	Mr. Bjarne Kristiansen, P.G.	From:	Daniel D. Overton, P.E.
Company:	Wyoming Department of Environmental Quality – Land Quality Division	Date:	March 15, 2019
EA No.:	110875		Professional Engineer (Civil) DANIEL D. OVERTON 8209 Date 3/15/19 WYOMING
Re:	Review of Round 8 Technical Review Response to Comments Specific to Subsidence, Brook Mine Permit to Mine Application (TFN 6 2/025)		

1.0 INTRODUCTION

Engineering Analytics, Inc. (EA) was tasked by the Wyoming Department of Environmental Quality (DEQ) Land Quality Division (LQD) to provide an evaluation of subsidence-related documentation regarding the Brook Mine Permit to Mine Application (Permit Application) (TFN 6 2/025). The Brook Mine is a sub-bituminous coal mine located approximately 8 miles north of the City of Sheridan in Sheridan County, Wyoming. On September 27, 2017, the State of Wyoming Environmental Quality Council (EQC) issued *Findings of Fact, Conclusions of Law, and Order (Order) regarding Docket 17-4802, In Re Brook Mine Application (TFN 6 2-025)* (Order).

EA has reviewed previous Permit Application submittals as documented in memorandums to the DEQ on June 29, 2018 and January 14, 2019. The DEQ provided comments to the Brook Mine in the Round 8 Technical Review, Brook Mine Coal Mine Permit Application, TFN 6 6/025, dated January 17, 2019.

This Technical Memorandum provides an evaluation of the subsidence-related responses and modifications made to Permit Application documentation in the Brook Mine's response to the Round 8 Technical Review. The documents reviewed include:

- Mine Plan, Section MP.13 Subsidence Control dated February 2019 (page MP-65).
- Mine Plan Addendum MP-6 Subsidence Control Plan, Round 8 dated March 2019 (pages MP-6-3 through MP-6-9).
- Response to comments, specifically comments from Bj (Numbers 2 through 4). In addition, the responses were searched for relevant key terminology (e.g., subsidence, strength, SAP, sampling and analysis).
- The RAMACO LLC Index Sheet for Mine Permit Amendments or Revisions dated March 4, 2019, TFN 6 2/025 (pages 1 through 5). This document was cross-checked to identify any relevant subsidence-related changes to text, tables or figures.

Exhibit 3

2.0 SUBSIDENCE-RELATED ROUND 8 SUBMITTAL RESPONSES

Comments from Mr. Kristiansen:

2) Based on the Subsidence Plan, coring was to be conducted at two locations to obtain samples for subsidence materials testing. In addition, the Subsidence Plan states that strength testing will be performed on roof, coal, and underburden core samples for the first highwall panels proposed for years 6 through 10, with strength testing on future panels occurring prior to mining. There does not appear to be a discussion in the Subsidence Control Plan or in the Agapito Report for an additional borehole core testing as indicated in the Subsidence Plan, or for demonstration of how much geotechnical testing is suitable. **The applicant should indicate whether there are plans for an additional borehole analyses for this panel and how will physical characterization be performed for the additional panels in the mine plan and for potential subsidence.**

AAI Response: The corehole tested (2017-4) provides adequate data for the study area addressed in Agapito's report. In future highwall mining blocks outside the study area, additional hole(s) covering a similar area are appropriate, with a similar suite of tests (approximately 20 UCS tests, 10 point load tests, and 5 slake durability tests) of the upper and immediate roof, Carney Seam, and floor. The text in Addendum MP-6 has been updated.

> **EA Comments on Round 8 Responses:** The text from Addendum MP-6 Round 8 was checked, and under Section MP-6.1 Highwall Mining Plan, the last paragraph, on page MP-6-4, a new sentence was added at the end of the last paragraph to read:
> *"In future Highwall mining blocks outside the study area, additional hole(s) covering a similar area are appropriate, with a similar suite of tests (approximately 20 UCS tests, 10 point load tests, and 5 slake durability tests) of the upper and immediate roof, Carney Seam, and floor."*
>
> This new text, acknowledged by the Brook Mine, indicates that the geotechnical testing to date is satisfactory for this panel and that similar geotechnical testing will be performed to address the concerns of subsidence in areas of potential mining.

3) The Subsidence Control Plan provides for monitoring, and in the event of subsidence, provides plans for reclamation. **The applicant should indicate the specific plan, or best practices implemented to perform subsidence evaluations in the event of unexpected subsidence.**

AAI Response: The best practice is to establish the pre-mining surface topography over the highwall mined area, and perform additional survey(s) if/when subsidence is suspected, or on an annual basis, to detect changes from the baseline topography (i.e. subsidence). There are various combinations of satellite, aerial and drone-based systems to accomplish this; a drone-based photogrammetry system is adequate and likely the most cost-effective.

> **EA Comments on Round 8 Responses:** The text from Addendum MP-6 Round 8 was checked, and in Section MP-6.3 Subsidence Monitoring and Assessment, second paragraph, the first sentence on page MP-6-8 was modified as follows with new text underlined: "*The surface of each individual areas to be highwall mined will be evaluated 6 months prior mining <u>with satellite, aerial, and/or drone-based system</u> to determine if there are pipelines, structures, streams or and other items that could be impacted by potential subsidence due to the highwall mining. Any items found during this evaluation will be inspected and documented as their pre-mining condition.*"
>
> This new text, acknowledged by the Brook Mine, indicates that state-of-the-art, or best practices available, will be used to provide a baseline of the pre-mining topographic area.

4) The recommendations for the thickness of leaving coal on both the roof and the floor appear to vary and suggest dependency upon the materials encountered in the floor. An allowance for leaving coal on both the floor and roof seems feasible for the design. **The applicant should, however, make a specific recommendation for the thickness of coal to be left on the roof and the floor.**

AAI Response: The need to leave roof or floor coal is driven by the roof or floor conditions encountered during mining. Under normal conditions, it is expected that the roof and floor will remain stable while the mining machinery is in the hole, even if no roof or floor coal is left. Therefore, our base recommendation is that no roof or floor coal is required to be left. If however small falls of roof material occur during mining, leaving 6 to 12 inches of roof coal should alleviate the problem, based on experience. Similarly, our analyses indicate that the floor should remain stable, with no pillar punching, without leaving floor coal. If however trafficability proves to be an issue, leaving 6 to 12 inches of floor coal should remedy the problem.

> **EA Comments on Round 8 Responses:** The text from Addendum MP-6 Round 8 was checked, and in Section MP-6-1 Highwall Mining Plan, third paragraph, page MP-6-3, the following sentences were added: "No roof or floor coals is left. If small falls of roof material occur during mining, leaving 6 to 12 inches of roof coal should alleviate the problem. If trafficability proves to be an issue, leaving 6 to 12 inches of floor coal should remedy the problem."
>
> This new text clarifies the intent of Brook Mine, of whether and under what conditions coal may be left on the top and bottom of the seam.

3.0 REFERENCES

RAMACO, 2019. Index Sheet for Mine Permit Amendments or Revisions, Broom Mine, TFN 6 2/025, RAMACO, LLC. March 4, 2019, 5pp.

RAMACO, 2019. Addendum MP-6 Subsidence Control Plan, Brook Mine Permit Application, TFN 6 2/025, Volume XI, Mine Plan, March, 2019, 9pp.

State of Wyoming Environmental Quality Council, 2017. Findings of Fact, Conclusions of Law, and Order, Docket 17-4802, In RE Brook Mine Application, TFN 6 2-025, filed September 28, 2017.

WWC Engineering, 2019. Response to WDEQ-LQD Round 8 Technical Review, Brook Mine Permit to Mine Application, TFN 6 2/025, prepared by WWC Engineering, submitted to Wyoming Department of Environmental Quality.

WWC Engineering, 2019. Mine Plan, Brook Mine Permit Application, Volume XI, February, 2019, 99pp.

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Technical Memorandum

To:	Mr. Bjarne Kristiansen, P.G.	From:	Daniel D. Overton, P.E.
Company:	Wyoming Department of Environmental Quality – Land Quality Division	Date:	June 9, 2020
EA No.:	110875		Professional Engineer (Civil) DANIEL D. OVERTON 8205 Date 6/9/2020 WYOMING
Re:	Review Response to Public Comments and Informal Conference, Issues Specific to Subsidence, Brook Mine Permit to Mine Application (TFN 6 2/025)		

1.0 INTRODUCTION

Engineering Analytics, Inc. (EA) was tasked by the Wyoming Department of Environmental Quality (DEQ) Land Quality Division (LQD) to provide an evaluation of subsidence-related public comments to the Brook Mine Permit to Mine Application (Permit Application) (TFN 6 2/025) which were received by the DEQ in April 2020, and subsidence-related oral comments provided during the DEQ Brook Mine Informal Conference conducted on May 13, 2020.

1.1 Documents Reviewed

EA has reviewed previous Permit Application submittals as documented in EA memoranda to the DEQ dated June 29, 2018, January 14, 2019, and March 15, 2019 (see References). In addition to the permit documents we have reviewed previously, we reviewed public comments submitted to the DEQ by the following:

1. Shannon Anderson (April 23, 2020). Includes the following as attachments: an Expert Report written by Marino Engineering Associates, Inc. (MEA) regarding mine subsidence, dated April 15, 2020; a Memorandum from Mike Wireman of Granite Ridge Groundwater dated April 16, 2020.
2. James Aksamit (undated).
3. Christine M. Anderson (April 15, 2020).
4. John and Shelley Barbula (April 17, 2020).
5. Bill Bensel regarding Ramaco Brook Mine, dated April 23, 2020.
6. Big Horn Coal Company (April 23, 2020).
7. Anton Bocek (April 5, 2020).
8. John P. Buyok and Vanessa Buyok (April 23, 2020).
9. Wendy Condrat (undated).
10. Louisa Crosby (undated).
11. Mary Brezik-Fisher and David Fisher (April 23, 2020)

Exhibit 4

12. Gillian Malone (undated).
13. Pam Marks (undated).
14. Author unknown (undated).
15. Joan Tellez (April 8, 2020).

We also reviewed public comments provided to the DEQ during the Informal Conference conducted on May 13, 2020. We reviewed the recorded video oral comments provided by Dr. Gennaro Merino of Merino Engineering Associates, Inc. (MEA) and Tim Ross of Agapito Associates, Inc. (AAI).

1.2 Scope of Review

Our review was limited to issues related to potential mine subsidence in the highwall mining area. Our review was also limited to the portion of the proposed mining area currently under permit review. It's our understanding that the current permit review entails a 5-year period and includes the surface mine and panel TR-1 only, as shown on Figure 1. Public comments pertaining to mining in areas outside of this area, including mining of the split Carney Seam, are not addressed in this technical memorandum.

2.0 SUBSIDENCE-RELATED REVIEW COMMENTS

Based on our review of the written public comments, recorded video oral comments, and documents provided to us previously, we provide the following comments.

2.1 Additional Core Holes

It appears that Agapito (AAI, 2018) relied upon the geotechnical parameters from a single core hole (2017-4) for their geotechnical analysis, modeling and subsidence prediction. The location of core hole 2017-4 is shown on Figure 1. Reference is made in AAI (2018) to additional holes which were used to develop the stratigraphic model, but the specific holes used are not referenced, nor are the associated logs provided.

In an earlier phase of the permitting process, the drilling of additional core holes and geotechnical testing was proposed by Ramaco. We reviewed the proposed Sampling and Analysis Plan (SAP) in a previous Technical Memorandum (EA, 2018). The additional sampling and analysis proposed by Ramaco in their SAP was not performed.

In our opinion, the single core hole (2017-4) does not adequately characterize the stratigraphy or the geotechnical properties of the rock in the immediate area of the proposed TR-1 highwall mining area. From our review of the maps and geologic cross sections in Appendix D5 (Ramaco, 2019a), we note that most of the existing core holes are located well to the west of the TR-1 area. These core hole locations have been overlaid onto the overall mine plan on our Figure 1. We reviewed Cross-Section K-K' on Sheet 14 of Addendum D5-3 Exhibit 2, and it appears that the closest core holes to 2017-4 are 578409 and 578415 which are located well outside the proposed TR-1 mining area at a distance of approximately 3,100 and 3,300 feet from core hole 2017-4, respectively (see Figure 1). In our opinion, this distance between core holes is excessive and does not allow an adequate characterization of the TR-1 area. We recommend that additional core holes be drilled within the TR-1 boundary, especially since this area will be the first area to be highwall mined.

Dr. Marino expresses a similar concern regarding the use of the single core hole in his written report (MEA, 2020) and in his oral comments during the Informal Conference. In bullet #1 on page 4 of his report (MEA, 2020) he states the following:

> *"The one geotechnical boring which was done in the TR-1 area, which is [the] proposed first area to be highwall mined. This boring indicated the roof and floor contains anomalous rock conditions compared to other borings drilled in the application area. Therefore, applying these rock conditions and associated test data to all of the application area or, for the matter, all of TR-1 appears inappropriate."*

It appears from our review that there is some uncertainty regarding the stratigraphy in the area of TR-1. In the fourth paragraph in Section 2.1 on page MP-6-24 of AAI (2018), Agapito discusses the contours of depth of cover, coal seam thickness, etc. shown on Figures 2 through 7 of their report. The paragraph includes the following:

> *"The slope variations seen in the plots seem unusually severe and apparently coincide with the drill holes that were used to construct the contours. It is possible that different series of holes were surveyed and interpreted differently, and the data may contain discrepancies that account for the slope variations. Also, unmapped faults may exist that complicate the seam structure."*

The additional core holes recommended herein should provide additional information regarding the overall stratigraphy, the thickness and extent of the various lithologic units, and the presence of faults that should supplement the applicant's current understanding of the conditions in the proposed highwall mining area.

Furthermore, additional core holes will allow the applicant to better evaluate the strength of the stratigraphic units, in particular the carbonaceous mudstone and mudstone layers which will form the immediate floor of the highwall openings. AAI (2018) describes this material as "weak." AAI (2018) states the following in the first paragraph in Section 2.2.2 on page MP-6-33:

> *"The floor is also composed of carbonaceous mudstone underlain by a weak mudstone."*

In discussing floor stability in the first paragraph in Section 3.4 on page MP-6-38, AAI (2018) states:

> *"The proposed highwall panel pillars are underlain by a thin layer (approximately 2 ft thick) of a weak carbonaceous mudstone (CMS). The laboratory tests (Table 1) indicate a moisture content of 18% for the CMS layer, which tends to weaken such shale-related rocks. Weak floor layers can adversely affect pillar and flor stability as well as the efficiency of mining operations through possible mechanisms of floor heave and pillar punching."*

We reviewed the Rock Mechanics Testing report in Appendix B of AAI (2018). A limited amount of geotechnical testing was performed on the carbonaceous mudstone which will comprise the immediate floor of the highwall openings and pillars. For example, only a single Uniaxial Compressive Strength (UCS) test was conducted for the carbonaceous mudstone (Specimen UCS-16/E). The additional core holes recommended herein should provide additional samples for geotechnical testing which will allow Ramaco and AAI to better evaluate the strength of the stratigraphic units in the proposed highwall mining area, especially the weak units which will comprise the floor.

Determining the sufficient number of core holes to adequately characterize a proposed new underground mining area is somewhat subjective and depends upon many factors. Some researchers have found geostatistical analysis to be useful in determining the maximum spacing between boreholes to adequately characterize coal mine units (Ledvina et al., 1994). We recommend that a geostatistical analysis be performed to determine the adequate number of borings, and that the minimum of two additional core holes be drilled and sampled in the proposed TR-1 highwall mining area. We recommend that the location of the core holes and the associated sampling program be determined by Ramaco in consultation with their geotechnical consultant (AAI) to ensure the data collected meet AAI's needs for modeling and subsidence evaluation.

The data provided from the additional core holes will supplement the currently-available data and allow AAI to refine their analyses and subsidence predictions, and allow Ramaco to revise their Subsidence Control Plan for TR-1 if necessary.

2.2 Geotechnical Testing for Subsidence Evaluation

Samples collected from the additional core holes should include the roof, coal, and floor of the proposed highwall mining area, with special attention paid to the "weak" carbonaceous mudstone and mudstone which will underlie the tunnel openings and pillars. The suite of testing should be similar to that performed by AAI for core hole 2017-4 (including tensile strength, uniaxial compressive strength, axial and diametral point load testing) and any other testing deemed necessary by AAI for a thorough analysis. All testing should be performed in accordance with applicable ASTM standards.

The geotechnical testing should also include testing to evaluate the long-term strength of the roof and floor materials. Dr. Marino expressed concern regarding the long-term strength of the floor layers on pages 7 through 9 and bullet #5 on page 16 of his written report (MEA, 2020), and in his oral comments during the Informal Conference. We recommend that the testing include Atterberg Limit testing to evaluate the plasticity of the roof and floor units, as well as consolidated-drained triaxial testing to better evaluate the long-term strength of the roof and floor.

The geotechnical data collected from the additional core holes will allow AAI to refine their analyses and subsidence predictions, including the long-term stability of the overall highwall mining area, and allow Ramaco to revise their Subsidence Control Plan for TR-1 if necessary.

2.3 Abandoned Mine Lands Standards

In his oral comments during the Informal Conference on May 13, 2020, Dr. Marino of Merino Engineering Associates, Inc. (MEA) states (at approximately 3:53 in the recorded video oral comments) that the Abandoned Mine Lands standards don't appear to be being applied in the Brook Mine permitting process. He does not specify which standard is not being applied. We reviewed his report (MEA, 2020), and we cannot find reference to a specific standard that is not being applied.

We have previously reviewed the applicable standards, as documented in our Technical Memorandum dated January 24, 2019 (EA, 2019a). Our conclusion is repeated below:

A review of the Department of Environmental Quality (020) regulations related to Land Quality – Coal (0006) of the Wyoming Administrative Code (WAC) were reviewed in regards to subsidence for underground coal mining. Pertinent sections with citations relevant to subsidence include:

- Chapter 1: Authorities and Definitions for Surface Coal Mining Operations (020.0006.1.08272014)
- Chapter 2: Permit Application Requirements (020.0006.2.08272014)
- Chapter 4: Environmental Protection Performance Standards (020.0006.4.12172012)
- Chapter 7: Underground Coal Mining (020.0006.7.04112011)

In general, the Subsidence Control Plan and the Agapito Report appear to provide information requested by the code related to evaluating for the potential of subsidence for the planned underground coal mine. The documents provide geotechnical analyses based on local core, with standard approaches to design for stability with the intent to minimize subsidence, as well as provide for monitoring and remediation in the event of subsidence.

2.4 Applicability of Subsidence Control Plan

The Subsidence Control Plan in Addendum MP-6 dated March 2019 (Ramaco, 2019b) is written in such a way that Ramaco seems to intend it to apply to all proposed highwall mining areas, even areas outside of TR-1 and areas where multiple seams will be mined. The following is stated in the first paragraph in Section MP-6.1 on page MP-6-3:

> *"The majority of highwall mining will be conducted in the two splits of the Carney seam. West of the Carney Seam's split line shown in Figure MP-6.1-1, the highwall mining activity will be concentrated primarily in the Carney lower split due to its greater thickness. East of the split line the two splits merge allowing full seam thickness extraction within the limits of the highwall mining machine. Figure MP-6.1 also shows the additional highwall mining planned in the lower Master's seam."*

The Subsidence Control Plan also first paragraph on page MP-6-8:

> *"Highwall miner holes will be oriented in the same azimuth as the holes in the Carney Seam located directly above. Its pillar dimensions will be sized based on the thicker Carney Seam so that 'pillar stacking' is achieved."*

It must be noted that the Agapito report (AAI, 2020), included in the Subsidence Control Plan as Attachment MP-6-A, evaluated highwall mining in the area of TR-1 only, where the single Carney seam is proposed to be mined. It does not include any analyses of highwall mining outside of the TR-1 area, or areas where multiple seams will be mined, or "pillar stacking." Therefore, it simply does not apply to proposed mining areas other than TR-1. In our opinion, the Subsidence Control Plan should be revised to apply only to the open pit and TR-1 area that is being permitted at this time.

2.5 Web Pillar Stability

AAI (2018) states the following in the fourth paragraph in Section 4.2 on page MP-6-42:

> *"The design charts shown in Figures 9a through 9c are based on the ARMPS recommended web pillar stability factor of 1.6. An additional set of design curves were prepared using a more*

conservative value of 1.8, to further reduce the potential for pillar failure. The charts are included in Appendix C if Ramaco wishes to use the more conservative design."

EA recommends that the applicant indicate which web pillar stability factor (1.6 or 1.8) will be used during highwall mining.

3.0 REFERENCES

Agapito Associates, Inc. (AAI), 2018. *Geotechnical Design and Operational Considerations for Highwall Mining – Brook Mine.* Prepared for Ramaco Carbon. September 13.

Engineering Analytics, Inc. (EA), 2018. Technical Memorandum regarding Review of Brook Mine Subsidence Sampling and Analysis Plan. Prepared for Wyoming Department of Environmental Quality – Land Quality Division. June 28.

Engineering Analytics, Inc. (EA), 2019a. Technical Memorandum regarding Review of Brook Mine Permit to Mine Application Specific to Subsidence: Response to EQC Finding of Facts and Conclusions of Law, WDEQ Comments Round 7, and supplemental Materials. Prepared for Wyoming Department of Environmental Quality – Land Quality Division. January 24.

Engineering Analytics, Inc. (EA), 2019b. Technical Memorandum regarding Review of Round 8 Technical Review response to Comments Specific to Subsidence, Brook Mine Permit to Mine Application (TFN 6 2/025). Prepared for Wyoming Department of Environmental Quality – Land Quality Division. March 15.

Ledvina, C.T., Dowding, C.H., Fowler, S., Hunt, G. and Nance, R., 1994. *Geostatistical Guidance of Exploration in Roof Control – How many Drill Holes are Enough?* Proceedings of the 5th Conference on Ground Control for Midwest U.S. Coal Mines, Collinsville, Illinois, pp. 14-30.

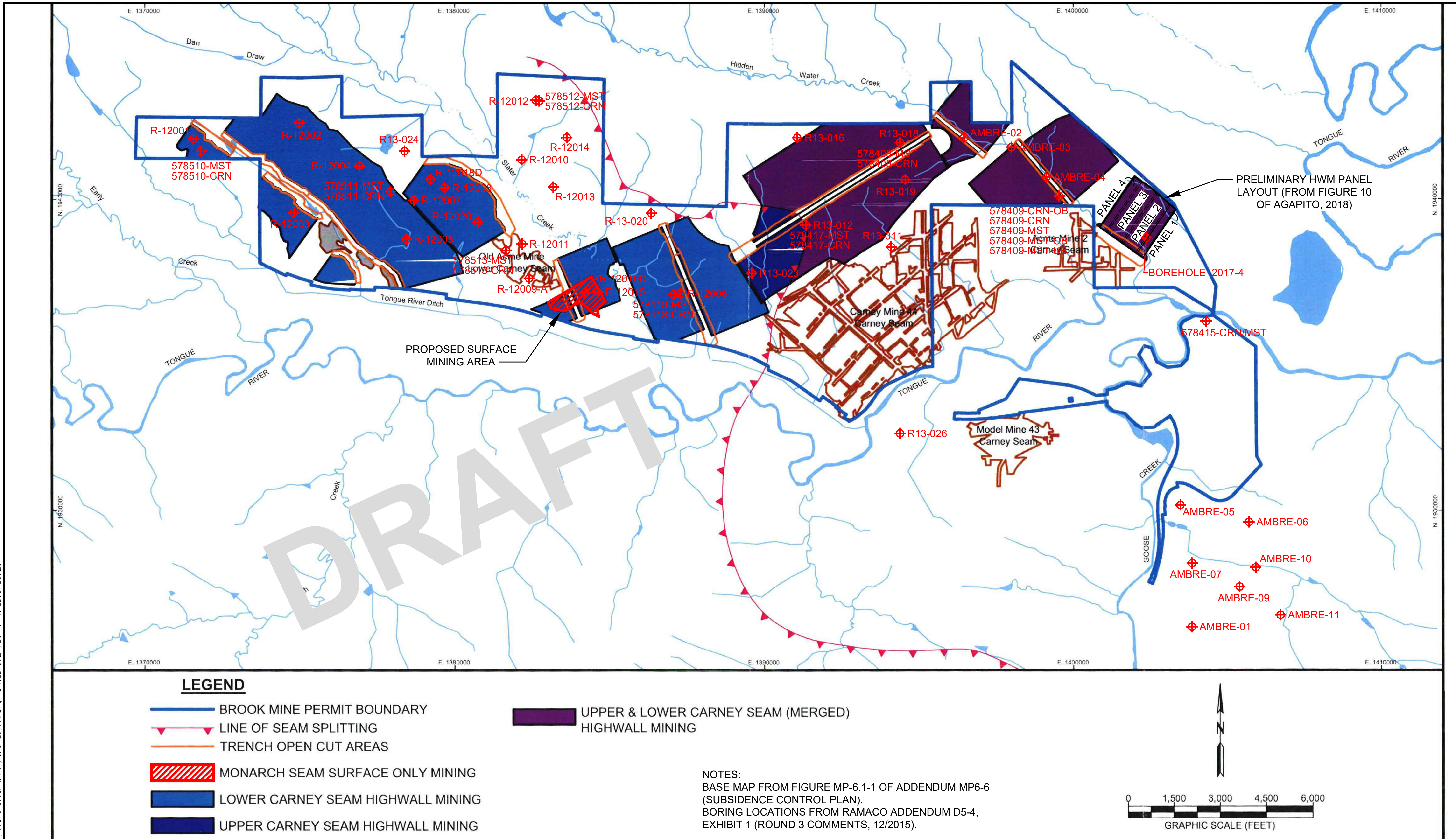
Merino Engineering Associates, Inc. (MEA), 2020. Letter to Ms. Shannon Anderson, Acting Director, Powder River Basin Resource Council regarding Review of Brook Mine Application. April 15.

RAMACO, 2019a. Appendix D5, Topography, Geology and Overburden Assessment, Brook Mine Permit Application TFN 6 2/025. In Volume IV. December.

RAMACO, 2019b. Addendum MP-6, Subsidence Control Plan, Brook Mine Permit Application TFN 6 2/025. In Volume XI, Mine Plan. March.

RAMACO, 2019c. Volume XI, Mine Plan, Brook Mine Permit Application TFN 6 2/025. December.

FIGURE



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Project No. 110875

May 2020

Engineering Analytics, Inc.

FIGURE 1
OVERALL PROPOSED MINING AREA WITH CURRENTLY-PROPOSED HIGHWALL MINING AREA
BROOK MINE, SHERIDAN COUNTY, WYOMING

EXPERTISE

Mr. Overton is President and Principal Geotechnical Engineer at Engineering Analytics and has over 35 years of geotechnical design and reclamation engineering experience on a diversity of projects including mine design and mine reclamation projects. Mr. Overton has served as Project Engineer or Project Manager for a variety of mining projects across the U.S. including reclamation and closure plans, pit slope analyses, cover designs, tailings impoundment design and construction, waste rock disposal plans, heap leach pads, and process solution ponds. Mr. Overton has represented the owner for closure of the Uravan site with the CDPHE, was the design engineer of record for the closure plan of the Gas Hills site under NRC jurisdiction, was a design engineer of the tailings impoundment at the Shootaring Mill, and is currently the engineer of record for the Sheep Mountain heap-leach pad, which will be the first heap-leach pad permitted through the NRC. Mine sites have included uranium, gold, copper, gravel, and limestone mine and mill facilities. His technical specialties include cover design, tailings consolidation analyses, seepage and groundwater analyses, stability analyses, infiltration modeling, and developing grading plans, quantities and costs. Mr. Overton is a Fellow of ASCE and is a Facility Affiliate at Colorado State University, having served on various thesis and dissertation committees. He is also a permanent committee member and chairman of the annual Tailings and Mine Waste conferences, and is knowledgeable about the key technical issues and research applicable to waste rock, tailings, and other mine materials. Mr Overton has written approximately 50 technical papers addressing multiple aspects of geotechnical engineering, and is a co-author of the text book titled "Foundation Engineering for Expansive Soils".

Mr. Overton has provided mining-related technical review services for a variety of public entities including the Land Quality Division of the Wyoming Department of Environmental Quality, the Colorado Division of Reclamation, Mining and Safety, and the Virginia Department of Environmental Quality. These services have included technical reviews of specific projects as well as technical input into the development of regulatory guidelines and regulations. Mr. Overton has also been designated as the EPA's technical expert with regards to determining closure scenarios for the waste rock piles as the Questa Mine in New Mexico.

Mr. Overton has provided mining-related forensic investigations for a variety of private and public clients including mining companies, law firms, and insurance companies. Mr. Overton has provided expert witness testimony on 25 occasions for a variety of projects including those involving mining projects, expansive soils, collapsible soils, and landslides. Several of these forensic projects have included failed mine tailings impoundments and covers.

REGISTRATIONS AND CERTIFICATIONS

Professional Engineer – Arizona, Arkansas, Colorado, Idaho, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oregon, Oklahoma, South Dakota, Texas, Utah, Washington, and Wyoming

Registered Civil and Geotechnical Engineer – California

OSHA 29 CFR 1910.120(e) 40-Hour HAZWOPER Training Course

OSHA 29 CFR 1910.120(e) 8-Hour HAZWOPER Supervisor Course

EDUCATION

M.S., Civil Engineering (Geotechnical Engineering), University of California, Los Angeles, California, 1988.

B.S., Civil Engineering, Minor in Mathematics, Colorado State University, Fort Collins, Colorado, 1985.

PROJECT EXPERIENCE

MINE FACILITIES OPERATIONS AND RECLAMATION

- **Babbit Ranches, Abandoned Uranium Mine Removal Action.** Principal Engineer for development of the removal action related to historic uranium mining activities on land currently owned by Babbit Ranches near Cameron, Arizona. The scope of work included development of a Health and Safety Plan, Quality Assurance Project Plan, Field Sampling Plan, Data Management Plan, Quality Management Plan, Background Determination and Gamma Scanning Plan, and development of Removal Site Evaluation. Review entities included USEPA Region IX, ADEQ, Arizona State Lands, Bureau of Reclamation, and the Navajo Nation.

- **Questa Molybdenum Mine.** Principal Engineer and member of Chevron's Technical Working Group for reclamation review for the Questa Molybdenum Mine near Questa, New Mexico. Responsibilities included development and review of reclamation plans for the superfund site. The project will reclaim the tailings piles taking into consideration slope stability, public concerns, and re-vegetation among other issues.

- **Northeast Church Rock, New Mexico.** Senior Staff Engineering Geologist for review of the Removal Action design for the Northeast Church Rock uranium mine.

Assisted lead Geotechnical Engineer in review of removal action plans and analyses.

- **Heap-Leach Design, Sheep Mountain, Jeffrey City, Wyoming.** Engineer of Record for the Heap-Leach Pad Design and Reclamation Plan for the Heap-Leach Pad for permitting of the first uranium ore heap-leach facility to be permitted by the NRC. Our scope of work included optimizing the heap-leach pad and mill site layout and developing the liner and collection pipe plans. Analyses included operational and post-closure stability of the heap-leach pad, cover design to include radon flux, freeze thaw, bio-intrusion, and cover cracking.

- **Shootaring Canyon Tailings Dam, Ticaboo, Utah.** Engineer of Record for the design of the Tailings Impoundment Reclamation. Provided geotechnical engineering for the Tailings Storage Facility Design Report. Both of these documents were prepared for submittal to the Utah Department of Environmental Quality in support of the permit application.

- **Design and Construction for Tailings Dam Raise, Hot Springs, Arkansas.** Project Manager and Geotechnical Engineer for design and construction of the reclamation and raise of a 125-foot-high tailings dam near Hot Springs, Arkansas. The project involved laying back the downstream face of the dam to a prescribed angle and concurrently raising and improving the dam for future operations.

- **Tailings Embankment Raise, Bunker, Missouri.** Project Manager for a third party review of a proposed 20-foot-raise of a 120-foot-high tailings embankment in Bunker, Missouri. The review was performed to identify areas of potential risk associated with the raise and included hydrology, slope stability, settlement/deformation, and construction issues.

- **Characterization of Tailings Disposal Facility, Owens Lake, California.** Project Manager and Geotechnical Engineer for the characterization of a sodium sulfate solid waste (tailings) disposal facility in Owens Lake, California. The characterization included studies of pile stability (geotechnical studies and ground penetrating radar), geochemical characterization, hydrology studies, geohydraulic analyses (involving installation of 45 piezometers and monitoring wells), and chemical transport modeling.

- **Instrumentation of Tailings Dam, Raton, New Mexico.** Project Manager and Geotechnical Engineer for design and installation of instrumentation to monitor the performance of a 200-foot-high tailings dam near Raton, New Mexico. Design of the spillway for the impoundment was also performed.

- **Design and Construction for Tailings Dam Reclamation, Hot Springs, Arkansas.** Engineer of Record for design and construction of the reclamation of a tailings dam near Hot Springs, Arkansas. The design included contouring of the tailings surface, design and placement of a multi-layer cover system, design of diversion channels and detention ponds, design of a spillway, and design for final vegetation of the reclaimed surface.

- **Tailings Impoundment Review, Hayden and Mission, Arizona.** Project Manager and Geotechnical Engineer for a third party review of Asarco properties in Arizona consisting of a 460-foot-high tailings dam at the Ray Mine, three tailings impoundments at the Hayden smelter, and eight tailings dams at the Mission complex. The review was performed to identify areas of potential risk associated with the operation of the facilities.

- **Tailings Dam Closure Alternatives, Olympic Dam, South Australia.** Project Manager for a study of closure alternatives of uranium tailings near Olympic Dam, South Australia. Various cover alternatives and costs were considered and human health and environmental risks were determined for the alternatives.

- **Detention Dam Design, Raton, New Mexico.** Project Manager and Geotechnical Engineer for design of a 35-foot-high dam for control of storm flow near Raton, New Mexico. The design included analyses of seepage slope stabilities of embankment and foundation materials and settlement/consolidation analyses of the foundation materials.

- **Review of Tailings and Waste Piles, Mantaro Valley, Peru.** Project Manager for a study of six mining sites in the Mantaro Valley of Peru. The study involved presenting options for minimizing environmental effects from the mining operations.

- **Reclamation Plan, Gas Hills Uranium Mine and Mill Site, Gas Hills, Wyoming.** Project Manager for Reclamation Plans of a Uranium Mine and Mill Site at Gas Hills, Wyoming. These plans were presented to the U.S. Nuclear Regulatory Commission for review and included a cover system and reclamation plan for an above-ground tailings impoundment, a below grade tailings repository, two evaporation ponds, and four mined ore pits. The geotechnical work included complete field investigation, installation of stand-pipe and multi-stage pneumatic piezometers, laboratory testing, and design including stability, seepage, deformation, settlement, radon attenuation, and infiltration analyses. A site-wide hydrology study was also performed which included surface water hydrology, hydraulic analyses, erosional analyses, riprap design, and bank stabilization of a creek adjacent to the above-grade tailings impoundment. A groundwater and geochemistry characterization study was performed, as well as radiological risk assessments and gamma surveys.

- **Reclamation Plan, Uravan Uranium Mine and Mill Site, Uravan, Colorado.** Project Manager and Geotechnical Engineer for reclamation plans for a uranium mine and mill at Uravan, Colorado. Services included evaluation and investigation of a reclaimed tailing dam, including review of historical reports and evaluation of settlement, lateral movement, piezometric data, and previously performed laboratory tests and analyses. The field investigation consisted of ten geotechnical borings and installation of nine slope inclinometers, three stand-pipe piezometers and seven multi-stage pneumatic piezometers. Geotechnical laboratory testing was performed, and seepage, stability, and deformation analyses were conducted. Geotechnical investigation of a proposed waste repository included slope stability analyses, immediate and long-term (creep) settlement, and analyses of horizontal strains and movement related to potential cracking of a design cover. Mitigation design of an inoperative spray field of radioactive raffinate included two options: a cover and an evaporative system. Services also included a Human Health Risk Assessment of mill wastes along a county road. The reclamation plans included design of a cover for a hazardous radioactive waste repository including routing of storm run-off around the repository and design of the diversions.

- **Impoundment Inspection, Cotter Uranium Mill, Cañon City, Colorado.** Engineer of Record for the annual impoundment inspections at the Cotter Mill facility. The inspection included observation of the embankments, liners, and drainage structures of the primary and secondary impoundments, the catch dam, and holding ponds. Water quality data, piezometer data, and survey data were reviewed for indications of leakage or settlement of the embankments. A report stating the inspection findings and recommendations for ongoing maintenance was provided.

- **Highland Uranium Mine, Glenrock, Wyoming.** Principal Engineer for an internal review of the proposed Closure Plan and ACL Application for the Highland Project prior to ExxonMobil submitting the plan to the NRC. Engineering Analytics review the hydrogeology, geotechnical engineering, geochemistry, and reclamation aspects of the proposed plan.

- **Schwartzwalder Uranium Mine, Golden, Colorado.** Engineer of Record for preliminary design of a waste rock repository for additional waste rock resulting from actions related to clean-up of old waste rock along the alluvial river bottom.

- **Canon City Milling Facility, Canon City, Colorado.** Provided engineering support for development of corrective measures. Prepared costs for various remediation alternatives. These documents were prepared for submittal to the Colorado Department of Public Health and Environment.

- **Uranium Study for Commonwealth of Virginia.** Principal Geotechnical Engineer for studies of current national and international regulatory programs for uranium mining and milling and preparation of documentation of the state of practice and best management practices for mine and mill waste management and disposal to assist the Commonwealth in preparation of updated regulations.

- **Underground Coal Gasification, Wyoming.** Engineer of Record for the review of an underground coal gasification permit for the Wyoming Land Quality Division. Our scope of work included the review of the settlement modeling, burn and subsidence monitoring system, and burn cavity predictions.

- **Gravel Quarry Expansion, Hunt East, Orland, California.** Conducted geotechnical investigation that included drilling and geotechnical laboratory testing to determine material properties. Performed slope stability analyses of final pit slopes and provided slope stability responses to the county for the gravel pit expansion.

- **Reclamation and Closure Plan, Red Dirt Pile, Empire Mine State Park, Grass Valley, California.** Engineer of Record for the reclamation design and construction QA of the Red Dirt Pile in the Empire Mine State Historic Park in Grass Valley, California. The Red Dirt Pile consisted of highly weathered rock that historically had a sulfide tailings stockpile during the mine operations from 1850 to 1956. The Red Dirt Pile was reclaimed and the reclamation design included development of a Storm Water Pollution Prevention Plan, regrading of the pile, design of a multi-layer cover system, design of diversion channels, design of a parking lot, and construction QA services.

- **Closure Design for Uranium Heap Leach Facility, Maybell, Colorado.** Project Manager for a closure design of a reclaimed heap leach facility at Maybell, Colorado. The reclamation plan was submitted to the State of Colorado Department of Public Health and Environment and included infiltration, seepage, and stability analyses, as well as development of a grouting plan for final closure.

- **Waste Rock Disposal Plan, Santa Maria, California.** Project Manager and Geotechnical Engineer for the design of waste rock disposal for a dimension stone quarry near Santa Maria, California. Also provided assistance with renewal of a permit with the United States Forest Service for the quarry.

- **Iron Mine Landfill Conversion, Chuckwalla Valley, California.** Geotechnical third party reviews of the Environmental Impact Study for conversion of Kaiser Steel's Eagle Mountain Iron Ore Mine into a landfill for non-hazardous materials. Eagle Mountain is a two-mile-long open pit mine located in the Chuckwalla Valley in Riverside County, California.

- **Heap Leach Pad Design, Moab, Utah.** Project Engineer for the geotechnical aspects of a 266-acre heap leach pad for a copper mine near Moab, Utah.

- **Reclamation Alternative Analyses, Campo Seco, California.** Project Engineer for determination of clean-up alternatives and a preferred approach alternative matrix for mitigation of acid-rock drainage from a waste rock dump at an abandoned copper mine near Campo Seco, California.

- **Heap Leach Pad Design, Cyclopic Mine, Dolan Springs, Arizona.** Project Engineer for the geotechnical exploration and design of a 25-acre heap leach pad and related facilities for a gold mine near Kingman, Arizona.

- **Reclamation Plan Design, Battle Mountain, Nevada.** Project Engineer for the geotechnical aspects of a reclamation plan for a proposed gold mine at Mule Canyon, near Battle Mountain, Nevada.

- **Ore Pad Design, Battle Mountain, Nevada.** Project Engineer for the geotechnical design of a 20-acre ore stockpile pad for a gold mine near Battle Mountain, Nevada.

MINING/INDUSTRIAL FORENSIC STUDIES

- **Tailings Dam Failure Investigation, British Columbia, Canada.** Project Engineer for investigation of the cause of a tailings dam failure at a copper/gold open pit mine. The project involved a review of dam design and analyses, government panel report, and providing responses to the potential modes of failure.

- **Tailings Dam Failure Investigation, Rock Springs, Wyoming.** Principal Engineer for investigation of the cause of a tailings dam failure at a trona mining facility in southwest Wyoming. The project involved a review of historic mining records, completion of a site visit, and review of the geochemistry of the tailings water. The tailings dam failed as a result of the dissolution of precipitates in the tailings used to construct the dam raises. The cause and nature of the failure was determined to be very complex because of the temperature variations between the tailings slurry and ambient temperature gradients within the impoundment. The temperature fluctuations that occurred during operation caused the deposited waste materials to alternately dissolve and re-precipitate as the tailings were deposited. This ultimately resulted in the formation of dissolution channels that reached the face of the impoundment resulting in a release of process water.

- **Talache Tailings Dam Failure, near Atlanta, Idaho.** Project Manager and Senior Geotechnical Engineer for technical evaluation of the causes of the Talache tailings dam failure. Work included hydrologic, seepage and water balance modeling, and stability analyses for the tailing impoundment. It also included a review of historic records of mill operations and evaluating and preparing cost estimates for measures that could have been implemented to avoid failure.

- **Hot Springs Tailings Dam Seepage Piping Analysis, Hot Springs, Arkansas.** Geotechnical Engineer for a forensic study into the causes of seepage and related piping through a tailing dam in Hot Springs, Arkansas. The seepage events occurred only after precipitation events. The results of the forensic study indicated that seepage and piping was related to chemical behavior of two generations of tailings during time and exposure to waters with various pH and TDS.

- **Tailings Pile Stability, Soledad Canyon, California.** Expert witness services and testimony regarding the geotechnical performance of a tailings pile for a rock quarry in Soledad Canyon, California.

- **Pinal Creek Contaminant Assessment, Globe/Miami, Arizona.** Project Manager for investigation of seepage from copper mine tailings to the groundwater. Analyses included seepage analyses, calculation of water balance, identification of seepage sources, and cost allocation for groundwater remediation.

- **Pit Wall Stability Investigation, Mesquite Mine, Brawley, California.** Performed anisotropic slope stability analyses of failed pit wall slopes, provided recommendations for future mining operations and closure buttresses of the pit walls. The analyses included developing geologic cross-sections from geologic mapping, performing additional strength testing for pit slope material, and analyzing historic and current geotechnical test results.

- **Slope Stability Investigation, Pikeview Quarry, Colorado Springs, Colorado.** Principal Engineer for a third-party review of a large slope failure at an active limestone quarry. The slide involved approximately 2 million tons of material and occurred due to daylighting of sedimentary bedding planes resulting from mining operations at the base of the mine highwall. The project included the review of project documents including historical mining operation and reclamation plans, geologic mapping, review and laboratory testing of rock core, two-dimensional and three-dimensional stability analyses for various operational scenarios, and the preparation of an opinion report detailing our analyses and opinions.

- **Monterey Mine Cover Failure, Albers, Illinois.** Principal Geotechnical Engineer for the investigation of the failure of the cover of the reclaimed refuse pile at the Monterey Number 2 Coal Mine. Analyses of the excessive surface bulges and cover failure was performed. Issues involved the pore-pressure of the refuse materials, the rate at which the cover was place, and the drainage provisions in the cover design.

- **Monterey Mine Slurry Wall, Albers, Illinois.** Engineer of Record for the investigation of slurry wall deficiencies located down gradient of the coal refuse disposal area. Our scope of work included drilling and installing temporary monitoring wells to delineate the plume. Completed a desk-top analysis of the water balance for the passive treatment system and the disposal area. Provided monthly review of the water quality data during pumping to try and capture the plume.

- **Third Party Review for Exxon Seeligson Gas Plant Remediation, Texas.** Principal Engineer responsible for reviewing historical documents pertaining to remediation of the Seeligson Gas Plant and preparation of a presentation to present findings. Also assisted in third party review of Exxon's Groundwater Vertical Migration Assessment and Vapor Intrusion Evaluation Plan.

- **Mission Bay Landfill, San Diego, California.** Expert witness services consisting of geotechnical review of available geotechnical data and consultation to the Office of the Attorney of the City of San Diego regarding construction claims for the Mission Bay Park and Landfill.

- **Landslide Investigation, Kemmerer, Wyoming.** Engineer of Record for the investigation and analyses of a slope failure that occurred during a state of Wyoming Abandoned Mine Lands (AML) mitigation of historic coal waste. The scope of work included drilling, sampling, and testing of the soil and rock located in the slide. Analyses included seismic, infiltration modeling, and slope stability analyses of the pre slide surface and temporary repair surface. We provided recommendations for additional mitigation efforts to stabilize the slope.

PROFESSIONAL EMPLOYMENT HISTORY

- Principal Geotechnical Engineer, President, Engineering Analytics, Inc., Fort Collins, Colorado (2008-present)
- Principal Geotechnical Engineer, Geotechnical Group Manager, Vice-President TetraTech/MFG, Inc., Fort Collins, Colorado (2001-2008)
- Senior Geotechnical Engineer, Staff Manager, Shepherd Miller, Inc., Fort Collins, Colorado (1994-2001)
- Field Technician, Engineering Assistant, Staff Engineer, Project Engineer, Principal Geotechnical Engineer, Vice-President, Geosoils, Inc., California (1984, 1986-1994)
- Junior Engineer, Empire Laboratories, Fort Collins, Colorado (1985-1986)

PROFESSIONAL AFFILIATIONS

American Society of Civil Engineers – Fellow, Diplomate of Geotechnical Engineering

- Northern Colorado Branch Past-President
- Past-Colorado Representative, District 16
- 150th Anniversary, Large Branch Award, Windsor Skate Park
- Public Service Award, Webelos Engineering Badge Day
- Outstanding Service Award

Adjunct Professor, Colorado State University

Tailings and Mine Waste Conference, Organizing Committee Past Chair, Colorado State University

Post-Tensioning Institute, DC-10 Slab-on-Ground Committee

American Council of Engineering Companies, Northern Region Director

Colorado Mining Association

Chi-Epsilon

Order of the Engineer

PUBLICATIONS

Shoop, Sally A. et. al. 2020 "Frost Action in Soils: Fundamentals and Mitigation in a Changing Climate" Part III Case Studies, Case Study 1, ASCE

Childress, T., et. al. 2019 "PTI DC10.5-19 "Standard Requirement for Design and Analysis of Shallow Post-Tensioned Concrete Foundations on Expansive and Stable Soils" Post-Tensioning Institute, June

Juedes, B., et. al. 2018 "PTI DC10.8-18 Guide for Performance Evaluations of Slab-on-Ground Foundations" Post-Tensioning Institute

Varnier, J.B., Cremeens, J.A. and Overton, D.D. 2018 "Three-Dimensional Slope Stability Analysis of Block Sliding Slope Failure at the Pikeview Quarry, El Paso County, Colorado", Mining Engineering Magazine, March.

Kuipers, J.R., Miller, D.J., Overton, D.D., Dawson, R.E., and Fisher, G., 2017 "The Development of Remedial Design Options for the Questa Mine Waste Rock Piles using a Collaborative Approach" Proceedings of the 21th International Conference on Tailings and Mine Waste, Banff, Canada, November 6 – 8.

Andrews, J.A., Overton, D.D. 2017 "Optimization of Facility Layout to Reduce Closure Costs" U2017 Global Uranium Symposium, Casper, Wyoming, August 23.

Nelson, E.J., Chao, K.C., Nelson, J.D., and Overton, D.D. 2017 "Lessons Learned from Foundation and Slab Failures on Expansive Soils.", Journal of Performance of Constructed Facilities. ASCE, Volume 31, Issue 3, June.

Varnier, J.B., Cremeens, J.A. and Overton, D.D. 2017 "Three-Dimensional Slope Stability Analysis of the Block Sliding Slope Failure at the Pikeview Quarry, El Paso County, Colorado", Proceedings of the Society of Mining Engineering annual Conference and Exposition, Denver, Colorado, February 22.

Bolis, J. L., McMahon, J. P., Overton, D.D., and Garcia, D., 2016 "The Technical Working Group Process – A Collaborative Approach to Long-Term Reclamation Concepts at the Questa Mine", Proceedings of the 20th International Conference on Tailings and Mine Waste, Keystone, Colorado October 2 – 5.

Chao, K.C. and Overton, D.D. Seminar - "Foundation Engineering for Expansive Soils." ASCE Los Angeles Section, Region 9, Ontario, CA, USA. September 19, 2016.

Horton, J., Overton, D.D., Butler, L., and Garcia, D., 2015 "Variability of Samples from Various Drilling and Sampling Methods", Proceedings of the 19th International Conference on Tailings and Mine Waste, Vancouver, British Columbia, Canada, October 26 – 28.

Nelson, J.D., Chao, K.C., Overton, D.D., and Nelson, E.J. 2015. "Foundation Engineering for Expansive Soils." John Wiley & Sons, Inc., New York, NY.

Andrews, J.S., Nelson, E.J., and Overton, D.D. 2015. "MSE Retaining Walls, Importance of Quality Construction and Engineering Oversight" Proceedings of the 2015 Geosynthetics Conference, Portland, Oregon, February.

Tocher, R.J., O'Brien, J, Chao, K.C., Overton, D.D. 2014. "Predicting Tailings Dam Failure and Release Volumes", Proceedings of the 18th International Conference on Tailings and Mine Waste, Keystone, Colorado, October 6 - 8.

Kang, J.B., Chao, K.C., Overton D.D., 2014 "Comparison of 1-D, 2-D, and 3-D Water Migrations Study in Expansive Soils" GeoShanghai International Conference 2014, ASCE Geotechnical Special Publication 236, May

Nelson, J.D., Chao, K.C., Overton D. D., Fox Z.P., Dunham-Friel, J.S., 2013. "Grouted Micropiles for Foundation Remediation in Expansive Soil (8th Michael W. O'Neill Lecture)", Deep Foundations Institute Journal, August

Nelson, J.D., Chao K.C., Overton D.D., 2013. "Design of Deep Pier Foundations for Expansive Soils", Geo-Strata, May/June.

Stoeber, J.N., Fox Z.P., Abshire M., Overton D. 2012. "Evaluating the Shear Strength of Mine Waste Rock", Proceedings of the 16th International Conference on Tailings and Mine Waste, Keystone, Colorado, October 14 – 17.

Nelson, J.D., Thompson E.G., Schaut R.W., Chao K.C., Overton D.D., and Dunham-Friel J.S. 2012. "Design Procedure and Considerations for Piers in Expansive Soils." American Society of Civil Engineers, Journal of Geoenvironmental Engineering, Vol. 138, No. 8, August.

Chao, K.C., Nelson, J.D., and Overton, D.D. 2012. "Factors Influencing Design of Deep Foundations on Expansive Soils." Proceedings of the 5th Asian-Pacific Conference on Unsaturated Soils, Pattaya, Thailand, November 14-16.

Schaut, R.W., Nelson, J.D., Overton, D.D., Carraro, J.A.H., and Fox, Z.P. 2011. "Interface Testing for the Design of Micropiles in Expansive Soils." Proceedings of the 36th Annual Conference on Deep Foundations, Boston, Massachusetts, October 18-21.

Nelson, J.D., Chao, K.C., Overton, D.D., 2011. "Discussion of "Method for Evaluation of Depth of Wetting in Residential Areas" by Kenneth D. Walsh, Craig A. Colby, William N. Houston, and Sandra L. Houston" ASCE Journal of Geotechnical and Geoenvironmental Engineering, March.

Nelson, J.D., Chao, K.C., Overton, D.D., and Dunham-Friel, J. 2011. "Evaluation of Level of Risk for Structural Movement Using Expansion Potential." Proceedings of the ASCE GeoFrontiers Conference, Dallas, Texas, March 13-16.

Overton, D.D., Chao, K.C., Nelson, J.D. 2010. "Water Content Profiles for Design of Foundations on Expansive Soils." Proceedings of the 5th International Conference on Unsaturated Soils, Barcelona, Spain, September 6-8.

Nelson, E.J. and Overton, D.D. 2010. "Water Migration in Pavement Subgrade." Proceedings of the 5th International Conference on Unsaturated Soils, Barcelona, Spain, September 6-8.

Chao, K.C., Nelson, J.D., Overton, D.D., and Nelson, E.J. 2010. "Commentaries on the Consolidation-Swell Test." Proceedings of the 5th International Conference on Unsaturated Soils, Barcelona, Spain, September 6-8.

Chao, K.C., Overton, D.D. and Nelson, J.D. 2010. "Effect of Water Sources on Water Migration in the Vadose Zone." Proceedings of the GeoShanghai International Conference, Shanghai, China, June 3-5.

Nelson, J.D., Overton, D.D., and Chao, K.C. 2010. "An Empirical Method for Predicting Foundation Heave Rate in Expansive Soil." Proceedings of the GeoShanghai International Conference, Shanghai, China, June 3-5.

Cumbers, J.M., Dornfest, E.M., Overton, D.D., and Harris, J. 2009. "Optimization of Compaction Grouting in Collapsible Soils." Proceedings of the 5th Congress on Forensic Engineering, Washington, D.C., November 10-15.

Malusis, M., Davis, M., Overton, D., Castelbaum, D., and Wright, T. 2009. "Development of Material and Compaction Requirements for a Mixed Clay/Sand Tailings Impoundment Liner." Proceedings of the Thirteenth International Conference on Tailings and Mine Waste, Banff, Alberta, Canada, November 2-4.

Davis, M., Abshire, M., Overton, D., Strachan, C., and Wright, T. 2009. "Best Available Technology Design for a Uranium Tailings Storage Facility." Proceedings of the Thirteenth International Conference on Tailings and Mine Waste, Banff, Alberta, Canada, November 2-4.

Andrews, J.S., Overton, D.D., and Legere, N. 2009. "Optimization of Removal of Overburden Material for an Open Pit Gold Mine." Proceedings of the Thirteenth International Conference on Tailings and Mine Waste, Banff, Alberta, Canada, November 2-4.

Overton, D.D., Nelson, J.D., and Chao, K.C. 2009. "Analyses of Frost-Migration Under Post-Tensioned Slabs." Proceedings of the 14th Conference on Cold Regions Engineering, September.

Chao, K.C., Nelson, J.D., and Overton, D.D. 2008. "An Evaluation of Soil Suction Measurements using the Filter Paper Method and Their Use in Volume Change Prediction." First European Conference on Unsaturated Soils, Durham, United Kingdom, July 2-4.

Chao, K.C., Nelson, J.D., and Overton, D.D. 2008. "Soil Water Retention Curves for Remolded Expansive Soils." First European Conference on Unsaturated Soils, Durham, United Kingdom, July 2-4.

Nelson, J.D., Chao, K.C., Overton, D. D. 2008. "Modeling Vadose Zone Water Migration Based on Downhole Nuclear Gauge Data." The 3rd International Conference on Site Characterization, Taipei, Taiwan, April 1-4.

Dornfest, E.M., Nelson, J.D., and Overton, D.D. 2007. "Case History and Causes of a Progressive Block Failure in Gently Dipping Bedrock." Proceedings of the 1st North American Landslide Conference, Vail, Colorado, AEG Special Publication No. 23, June.

Nelson, J.D., Chao, K.C., and Overton, D.D. 2007. "Design of Pier Foundations on Expansive Soils." Proceedings of the 3rd Asian Conference on Unsaturated Soils, April.

Nelson, J.D., Chao, K.C., Overton, D.D. 2007. "Definition of Expansion Potential for Expansive Soil." Proceedings of the 3rd Asian Conference on Unsaturated Soils, April.

Chao, K.C., Overton, D.D., and Nelson, J.D. 2007. "Case History of a Reactivation of a Landslide Due to Irrigation on Unsaturated Soil." Proceedings of the 3rd Asian Conference on Unsaturated Soils, April.

Overton, D.D., Chao, K.C., Nelson, J.D. 2007. "Heave Distress of a Manufacturing Building." Proceedings of GeoDenver 2007, New Peaks in Geotechnics, February.

Nelson, J.D., Chao, K.C., and Overton, D.D. 2007. "Development of Compressive Pier Force in Expansive Soils." Proceedings of GeoDenver 2007, New Peaks in Geotechnics, February.

Nelson, J.D., Overton, D.D., and Chao, K.C. 2006. "Evolution of Foundation Design for Expansive Soils." ASCE Geotechnical Practice Publication No. 4, Proceedings of the 2006 Biennial Geotechnical Seminar, November 10.

Chao, K.C., Overton, D.D., and Nelson, J.D. 2006. "Design and Installation of Deep Benchmarks in Expansive Soil." ASCE Journal of Surveying Engineering, August.

Dornfest, E.M., Nelson, J.D., and Overton, D.D. 2006. "Case History of Two Landslides in Lithostratigraphic Equivalent Formations." 40th Annual Symposium on Engineering Geology and Geotechnical Engineering, Utah State University, Logan Utah, May.

Chao, K.C., Overton, D.D., and Nelson, J.D. 2006. "The Effects of Site Conditions on the Predicted Time Rate of Heave." American Society of Civil Engineers, Special Publication 147, UnSaturated Soils 2006.

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The cases in which I have given testimony by deposition or trial are as follows:

Date Updated: June 3, 2020

LIST OF TRIAL/DEPOSTION TESTIMONY
Daniel D. Overton
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Engineering Analytics, Inc.

Deposition Date	Project No.	Case Name	Type of Testimony / Case No.	Trial Location	Attorney	Representing
6/3/2020	110851	Browning, et. al. vs. Lennar Colorado, LLC	Deposition 02-18-0002-6690	Englewood, Colorado	Craig S. Nuss Burg Simpson Eldredge Hersh & Jardine, P.C.	Plaintiff

Exhibit 6