Powder River Basin Resource Council

<div>Please see the attached objections and reports of Dr. Jerry Marino and Mike Wireman. I am also including the first part of Dr. Marino's report separately so it will be a smaller file - this file includes his comments on the 2020 permit application without the attachments. If you have any questions or have any difficulty with the files please let me know. I am working from home and available on my cell: 307-763-0995 or via email. Thank you - Shannon</div>

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POWDER RIVER BASIN
Resource Council

April 23, 2020

Alan Edwards, Deputy Director
Wyoming Department of Environmental Quality
200 W. 17th St.
Cheyenne, WY 82002
Submitted online via: http://lq.wyomingdeq.commentinput.com

Re: Objections to Brook Mining Co., LLC Coal Mining Permit Application & Comments on the Department of Environmental Quality Draft Cumulative Hydrologic Impact Assessment

Dear Mr. Edwards,

On behalf of the members of the Powder River Basin Resource Council ("Resource Council"), our organization hereby submits these objections to the proposed coal mining permit for Brook Mining Co., LLC ("Brook" "company" or "applicant") in Sheridan County. We also submit the following comments on the Department of Environmental Quality's ("DEQ") draft Cumulative Hydrologic Impact Assessment ("CHIA").

Pursuant to W.S. § 35-11-406(k), the Resource Council requests an informal conference with the Director to discuss our objections and comments. We request that such an informal conference be held in Sheridan, the location of the proposed mining operation. Given the complexity of the issues presented, and the current difficulties in scheduling such a public hearing during the COVID-19 pandemic, we will stipulate to hold the informal conference at a period beyond the 20 days provided for under subsection 406(k) of the Environmental Quality Act. In fact, as discussed below, if DEQ holds the informal conference during the pandemic, public participation rights will be violated.

Organizational Interest in the Coal Mining Permit

The Resource Council is a grassroots, member-based organization that has worked to address the impacts of coal mining on people and the environment since our inception in 1973.

Many of our members work, live, and recreate in Sheridan County adjacent to and on the site of the proposed Brook Mine permit. We have members who live next to the proposed Brook Mine permit boundary that will experience aesthetic impacts, impacts to their property, and impacts to their livelihoods as a result of the mine's proposed operations. We also have members that regularly travel the public roads within the mine permit boundary and members that frequently occupy public access and recreational areas within and in close proximity to the mine permit boundary. We are therefore an "interested person" within the meaning of W.S. § 35-11-406(k).

Given their proximity to the mine's proposed location, some of our members received personal notice of the opportunity to submit objections and will be submitting their own objections. Other members with recreational and aesthetic interests in the area will also be submitting objections. Our organizational objections are intended to supplement, not supplant, the individual objections of our members. However, their own stated objections and interests further support our organizational interest in the proceeding.

Objections and Concerns

1. Public Participation Violations During the COVID-19 Pandemic

At the outset, it is important for us to comment on the time we find ourselves in as we submit these comments. Wyoming, and most of the world, is grappling with the consequences of a global public health pandemic. Governor Gordon has issued orders to limit public access to government buildings, prohibit meetings of greater than ten people, and has otherwise encouraged and directed Wyomingites to stay home and refrain from unnecessary travel to limit infection to themselves and others.

a. Need to extend public comment period

We wrote to DEQ on March 23, 2020 requesting the agency to extend the comment deadline because locations where the permit application must be made available for review by the public (Sheridan County's courthouse and the Sheridan DEQ offices) were closed to regular public access. DEQ replied that a comment period extension was not needed because the permit application is available for download on the agency's website, and that the offices with hard copies remained accessible by appointment. While we appreciate the agency putting the application online, the size of the file has prevented easy downloading by some members of the public. Additionally, we remain concerned that there is a possible violation of federal and state laws and regulations that require public access to the permit application during all times of the comment period at the County Clerk's Office in the county in which the mine is located. *See* Wyo. Stat. § 35-11-406(d); 30 C.F.R. § 773.6(a)(2). We renew our request for DEQ to extend the public comment deadline until such a time as Wyoming, and Sheridan County, are not under any public health restrictions.

b. Requests for an informal conference & mine site visit must be placed on hold

We do not believe DEQ can lawfully hold an informal conference or other public hearing on the permit application so long as the public health orders are in place. DEQ regulations require an informal conference to "be held in the locality of the operation or at the state capitol, at the option of the requester." DEQ Rules of Practice and Procedure Ch. 3 § 3(a). Additionally, DEQ (and federal) rules provide that an objecting party may also request access to the proposed permit area through a site visit tour. Such a tour is open to any objecting party, and of course representatives of the agency and the permit applicant, who must be present if private lands must be accessed.

While the Resource Council hereby requests an informal conference in Sheridan County and a visit to the proposed permit area, we request that DEQ hold off on scheduling such public participation activities until the public health orders have been lifted. We do not believe there will be a way to meet the Environmental Quality Act's and SMCRA's mandates for public participation while public health restrictions are in place.[1]

If DEQ wishes to risk non-compliance and proceed with scheduling an informal conference and site visit, we welcome the opportunity to discuss the logistics surrounding the public participation opportunities, but our discussion or negotiations should in no way be viewed as waiving any objections we may have to the process itself.

2. DEQ violated the Environmental Quality Act by Not Requiring Brook to "Resubmit" its Permit Application Under Section 406(f)

Section 406(p) of the Environmental Quality Act dictates that once a hearing is held and the EQC issues its order, the mining permit should be issued or denied fifteen days after the order. Following, the EQC's decision the original Brook Mine permit application was denied. The EQC's Order and DEQ's denial of the application was not a "deficiency notice" under subsection 406(h) – it was a denial under subsection 406(p).

The Environmental Quality Act speaks directly to the case at hand in subsection 406(f) when a company "resubmits" an application. This is exactly what the EQC Order told the company to do – "revise" and "resubmit." Therefore, DEQ should have followed the process under subsection 406(f), which requires a sixty-day completeness review period of the resubmitted application, similar to subsection 406(e) for new permits. After the completeness review, the process is the same as new applications, with the requirements of subsections 406(g)-(p).

DEQ did not follow this process. Instead, it treated the EQC Order as "Round 7" of technical review under subsection 406(h).

Unfortunately, this led to real negative consequences for DEQ's ability to fully and fairly review the substantial changes to the company's permit application that were submitted in October 2018. Under the DEQ's process, staff members had a mere thirty days to review the new information submitted by the company under subsection 406(h) versus the time for completeness review under subsection 406(f) and the 150-day review period under subsection 406(h) for resubmitted applications. Given the public controversy and attention and important natural resources in the Tongue River Valley, it is not harmless error for DEQ to illegally restrict the time afforded to them under the Environmental Quality Act to fully review the resubmitted application.

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[1] For instance, please see the recent letter sent by Sweetwater County Commissioners to the BLM. We echo their concerns and comments: "Open public dialog cannot be replaced by Zoom and computerized meeting formats. Sweetwater County has participated in these types of meetings and have found them to be ineffective leaving many participants feeling frustrated and wondering if their comments were understood or would even be addressed." https://www.sweetwaternow.com/sweetwater-county-commissioners-request-rock-springs-rmp-be-postponed/

Additionally, because of this error, DEQ's process circumvented the public notice required in Section 406(g) for a resubmitted application.

We put DEQ on notice of these process violations by letter in February 2018, giving the agency ample opportunity to correct any violations before the October 2018 revised permit application submission. Unfortunately, DEQ proceeded with a process that is outside the scope of the Environmental Quality Act, therefore rendering any subsequent permit decisions illegal. To remedy this, DEQ must start over – by requiring Brook to resubmit a revised permit application under subsection 406(f), and subsequently following the process in subsections 406(g)-(p) for review of the resubmitted permit application.

3. Failure to Disclose Coal Mine Operators

As early as March 2015, our organization wrote to DEQ to express concern that the mine permit application did not contain "complete identification" of "[t]he names, addresses and telephone numbers of any operators, if different from the applicant" as required by the DEQ's rules. Land Quality Rules & Regulations (hereafter "LQRR") Ch. 2 § 2(a)(i). Upon our review of the application, Brook has not identified who the operator of the coal mine will be. The permit application refers to contractors or consultants but these parties are left unnamed. Additionally, it is our understanding that while Brook has a local "office," the company does not actually have staff that would be able to carry out mining activities should the company receive a permit. If any party other than Brook will be operating the mine, that party must be identified in the permit application. As you know, such identification is necessary for a complete applicant violator system ("AVS") check, but it is also required as part of the permit application for public notice and review.

4. The Permit Application Is Not Complete Because It Fails to Include All Coal Hauling, Processing, and Upgrading Facilities

For the purposes of delineating a permit boundary, the Environmental Quality Act defines "Surface coal mining operation" to mean surface lands where surface coal mining activities take place and/or surface lands "incident" to underground coal mining activities. The operation shall also "include any adjacent land the use of which is incidental to any of these activities, all lands affected by the construction of new roads or the improvement or use of existing roads to gain access to the site of these activities and for haulage . . . processing areas, shipping areas and other areas upon which are sited structures, facilities or other property or materials on the surface, resulting from or incident to these activities." W.S. § 35-11-103(e)(xx).

Here, the permit application fails to include associated facilities necessary to get coal to a point of sale, including necessary roads and facilities, and does not include the coal "processing areas" associated with the proposed industrial park and manufacturing facilities, which are incidental to the mine. The company's only stated source of coal for the proposed research park (iCam) and manufacturing center (iPark) is the Brook Mine.[2] Meaning, but for the Brook Mine, these facilities would not exist.

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[2] See https://ramacocarbon.com/facilities/

These SMCRA requirements have been interpreted by various courts, and judicial opinions provide instruction for including the facilities here. For instance, in 1992, the Alaska Supreme Court found that an eleven-mile access/haul road and adjacent conveyor from the mine site to a port, port facilities, a solid waste disposal facility, gravel pits, and a housing facility with an air strip and access road should have been considered as "incident" to coal mining activities. *Trustees for Alaska, Alaska Center for Environment v. Gorsuch*, 835 P.2d 1239 (1992).

Brook's permit is no different. If there are roads or facilities being used for mining operations and/or part of the process to get the coal from the mine to a point of use, those roads and facilities are "incident" to coal mining activities and require a SMCRA permit. The permit application is incomplete by not including these facilities.

5. The Permit Application is Not Complete and Accurate – It Is Too Vague and Unrealistic

The core of any coal mine permit is the mine plan. The mine plan establishes how much coal will be mined in what time period, and it describes the impacts to land, air, and water resources. It establishes the basis for the DEQ or impacted members of the public to enforce the terms of the permit, and the associated reclamation plan as the timing and measures needed in the reclamation plan are based on the mine plan, and if the mine plan is too vague or unrealistic, enforcement will prove problematic in the future.

DEQ regulations require information in a permit application to be "current" . . . "accurate and complete." DEQ Land Quality Division Rules and Regulations, Ch. 2 § 1. The mine plan must include "[a] complete operations plan proposed to be conducted during the life of the mine" with an accurate estimate of "the number of acres that will be affected annually" and the "anticipated annual and total production by tonnage." *Id*. at § 5(a)(i).

In the case of the Brook Mine, the mine plan is based on a plan that will never occur. The mine plan estimates annual production at a level that is in direct conflict with statements of the company's representatives explaining the company's plans for the area. And in fact, the company's own statements have contradicted each other.

Early statements by the company estimated 6-8 million tons a year of production over 20 years. Originally aimed at export markets, Ramaco then shifted its proposal to selling its coal locally for stoves or marketing it as "thermal coal" for power plants (arguing that private reserves and corresponding lack of federal royalties, along with "low cost" highwall mining, would make their coal marketable even in a down market). In 2014, Ramaco stated "Negotiations are currently underway with domestic utilities to purchase the majority of the of Brook Mine production."

But now, the company has shifted to using the coal for its proposed research and industrial facilities – a demand of which also contradicts the mine plan and show that its estimated production overestimates the amount of production. Ramaco executives are now stating that production will be on a "very limited basis" with "no more than a couple hundred thousand tons a year just to get started" and employment of "under 20 people."[3] Finally, company representatives have further represented that only *very* small amounts of coal would be needed for the research and processing facilities at the iPark and iCam. Atlas Carbon in Gillette, which produces carbon products for air and water treatment systems from coal currently uses around 30,000 tons of coal per year.[4]

Additionally, Ramaco's facilities are highly dependent on government funding, technology breakthroughs, and other unknowns that make them speculative. The company has not provided any justification for its thirty-nine year proposed mine life and/or the amount of coal it proposes to mine.

It is clear that the company's plans are in flux and the permit application is merely a placeholder for things yet to come. Our coal mining regulations require more; they require accurate, complete, and current information detailing anticipated production levels and an accurate, complete, and current estimate of the life of the mine. At the very least, the permit application should have fully disclosed that the company's plans are not finalized and the permit application should have presented a range of anticipated production, a range of operating years, or even production level alternatives based on different options of company investment, to allow DEQ to assess the completeness and technical adequacy of the permit application, along with any impacts to land, air, and water resources.

Consistent with Dr. Marino's recommendation discussed below, at the very least the permit application should be amended to limit mining to the first five years of surface mining. Even that portion of the mine is speculative, but it is less speculative than the remaining years for which Ramaco has not shown any proposed buyers or opportunities to use the coal.

6. The Permit Application Remains Deficient Regarding Baseline Water Testing and Hydrology Analysis

As the attached report from our hydrogeology expert Mike Wireman explains, the mining and reclamation plan does not include "a plan to minimize the disturbances to the prevailing hydrologic balance at the minesite and in associated offsite areas and to the quality and quantity of water in surface and ground water systems both during and after mining operations and during reclamation" as required by the Environmental Quality Act and corresponding DEQ regulations. W.S. § 35-11-406(b)(xvii). DEQ must deny the permit application *unless* it is sufficiently demonstrated that the proposed operations will not materially damage the hydrologic balance outside the permit area and will minimize disturbances to the prevailing hydrologic balance at the minesite.

Also as explained in the attached report, the permit application fails to protect the numerous AVFs in the permit area and adjacent areas as required by the Environmental Quality Act, SMCRA, and corresponding state and federal regulations.

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[3] *See* http://trib.com/business/energy/energy-journal-q-a-randall-atkins-ramaco/article_7834a593-c06d-5785-aeea-8f3b5637a337.html

[4] See http://www.energycapitaled.com/wp-content/uploads/2016/10/Presentation-6-Atlas-Carbon-Jim-Dye.pdf

7. The Permit Application Remains Deficient Regarding Subsidence Prevention

As discussed in the attached expert report from Dr. Jerry Marino, the subsidence control plan does not achieve its required objective: to control and prevent subsidence at the mine site. The expert report concludes that the subsidence remediation plan is inadequate.

Dr. Marino further concludes:

> As noted above, the permit application only addresses the highwall mining of the 68 acres of Carney Seam. With application approval, this may provide an administrative mechanism for DEQ to approve remaining underground mining of other mineable seam areas without proper public oversight via a non-significant revision to the permit. This would involve the entire 1,960 acres of proposed highwall mining.
>
> At a minimum, it is recommended that any highwall mining be removed from the permit until it is reasonably investigated in order not to setup such a precedent of unacceptable protocols. HWM areas should be applied for increments as Significant Revisions as proper subsidence engineering investigation is accomplished. Moreover, in the first 5 years on operation the Brook Mine intends on only surface mining with no highwall mining. This is also consistent with Ramaco's statement in the application that the permit will be renewed every 5 years (Mine Plan prepared by WWC Engineering dated 12/19). Another reason why the HWM application should be delayed and become a Significant Revision is the statement by Ramaco … "AAI agrees that reevaluation should be considered if the ultimate plan involves a greater cutting width, height, or penetration or a lesser production rate than assumed" (Ramaco Response to Round 8 DEQ Memo of Deficiencies dated January 9, 2018).

The company has an obligation to prevent subsidence. DEQ Land Quality Regulations require a coal mining permit application with underground components, such as this permit application, to include "[e]xcept for areas where planned subsidence is projected to be used, measures to be taken in the mine to prevent or minimize subsidence, including backfilling of voids and leaving areas in which no coal is removed." Ch. 7 § 1(a)(v)(C). Additionally, "[u]nderground mining activities shall be planned and conducted so as to prevent subsidence from causing material damage to structure, the land surface, and groundwater resources." Ch. 2 § 2(b)(iii).

The company is proposing to mine under at least one county road and will be mining in close proximity to numerous home and business structures, including cell towers, agricultural lands and associated structures, water wells, and public rights of way. Subsidence also has implications for whether the "reclamation plan can accomplish reclamation as required." *Id*. at § 406(n)(ii). And it has implications for creating damage to the hydrologic balance both within the permit area and in outside areas. *Id*. at §§ 406(b)(xvii), 406(n)(iii).

For the reasons stated in Dr. Marino's report and for the regulatory requirements discussed above, the permit application should be rejected. At the very least, as Dr. Marino concludes, the permit application should remove all highwall mine portions and limit the permit to the first five years of surface mining.

8. The Permit Application Does Not Adequately Disclose Impacts to Traffic & Road Use and It Does Not Contain the Required Traffic Plan

The mine plan does not estimate truck traffic, disclose any impacts to public or private roads used by the public, and does not include a traffic plan or any agreements with Sheridan County and/or the Wyoming Department of Transportation on road use, repair, and compensation. Additionally, the mine will directly impact Slater Creek Road, a county road that is the only access point for the property of Resource Council member Phil Klebba and his family at the Klebba Ranch. The mine plan does not provide the required buffer around Slater Creek Road or alternatively it does not provide a plan, approved by the Sheridan County Board of County Commissioners, to move the road.

Additionally, as discussed above, any roads used for mining operations or "incident" to mining operations require a SMCRA permit. Even if the company will be using state or county roads that are already in place, the use of those roads must be considered within the scope of the SMCRA permit.

9. The Permit Application Does Not Adequately Disclose Impacts to Conservation Easements and Recreation Access

While the permit application discloses that two walk-in areas for hunting and recreation are within the permit boundary (D1-7), it does not discuss how the use of these areas will be impacted by mining operations nor does it establish a plan to mitigate any impacts.

Additionally, the proposed mine and associated "industrial park" is located within eyesight of the Kleenburn Recreation Area, an area frequently used for recreation activities, including fishing, picnicking, and hiking. Again, the permit application fails to mitigate any impacts to recreation use in the area.

10. The Permit Application Continues to Fail to Include Necessary Controls and Restrictions on Blasting Intensity and Timing

While we appreciate the modifications made to the blasting plan, the plan remains deficient. The plan continues to fail to ensure that the requirements of Chapter 6 of the Land Quality Regulations will be met during mining and that offsite impacts resulting from pollution and seismicity will be prevented. Blasting is of particular concern to members of the public who recreate in the area given pollution and other impacts and to nearby homeowners and landowners whose structures could be impacted from blasting activities.

In particular, we ask that the DEQ restrict blasting operations to the weekdays only given the frequent use of the area for recreation during the weekends.

11. Failure to Include Information on an Important MSHA Requirement

The subsidence control plan references a "ground control plan" that is approved by MSHA and is commonly included for DEQ review in a subsidence control plan. However, no such plan exists. DEQ regulations require "[a] list identifying the Mine Safety and Health Administration identification number for all mine facilities that require MSHA approval and licenses, permits or approvals needed by the application to conduct the proposed operation, whether and when they have been issued, the issuing authority, and the steps to be taken to comply with the requirements" as part of the permit application. Ch. 2 § 2(a)(v). This information is not included in the permit application.

12. Water Rights & Use of the Tongue River

The mine proposes to use surface water rights to provide the majority of the mine's water supply. According to DEQ's analysis in the draft CHIA, any new surface water rights needed for water supply would be subject to approval by the Wyoming State Engineer under evaluation of the Yellowstone River Compact, which will require that bypass or make-up water be made available. However, the permit application is lacking in specific detail about the water rights that will be acquired and how the "bypass or make-up water" will be made available by Ramaco. If the mine is unable to acquire surface water rights, which may be very likely, it will be forced to use more groundwater, putting additional stress on the aquifer systems and potentially impacting nearby water wells.

13. Impacts from Flooding

Given that the area is in the Tongue River Valley with numerous tributaries and small streams, there are a variety of waterways that could be impacted by mining activities. Additionally, the area is prone to flooding, especially in high snowmelt runoff years. We are concerned that the sedimentation and runoff control structures identified in the mine plan will not protect impacts from flooding, especially when adding the water from mine dewatering activities. The analyses presented in the application regarding estimation of flood magnitudes and frequencies and volumes of water that will need to be managed (run-off / run-on) during mining operations did not consider extreme precipitation events. Given the occurrence of extreme events in the Tongue River Valley in recent years, it is important to model extreme events.

14. The Reclamation Bond Does Not Include Monitoring Costs

As discussed in Mr. Wireman's report, the water monitoring plan for the mine is deficient. The amount bonded for monitoring should be increased to reflect a revised and much more robust monitoring plan. Monitoring should include the costs for personnel and analysis, maintaining monitoring locations/sites/equipment, and developing new monitoring sites as appropriate. Any "additional cost to the state of bringing in personnel and equipment" should also be included.

15. The Reclamation Bond Does Not Include Costs to Restore Hydrologic Conditions

The bond fails to include sufficient funds to carry out all operations needed to restore to pre-mine hydrologic conditions within the permit area – and in any offsite areas that are impacted. At a minimum, there must be a thorough analysis of aquifer recharge capacity, what engineering techniques would be used to restore the aquifer to pre-mining capacity and water quality conditions, and what timetable and costs would be involved with such reclamation. The same must be done for surface water, and all associated costs must be included in the reclamation bond.

16. The Land Use Section of the Permit Application Must Be Updated

Ramaco incorrectly states in Appendix D1 that lands within the permit area have been used extensively for industrial purposes and that heavy industrial use is compliant with Sheridan County's land use plan. These incorrect statements must be revised. The proposed mining area is zoned for agricultural use and the only "light" industrial zoned land is where the proposed iCam and iPark facilities are located. These lands are not permitted for heavy industrial uses, and all mining lands must be returned to pre-mining land uses, including agriculture and recreation. An assumption of industrial use minimizes the reclamation expense to the mine operator, and limits the potential land use for future users.

Conclusion

Thank you for your time and consideration of these objections. We look forward to your scheduling of an informal conference to discuss these objections.

Sincerely,

Shannon Anderson
Staff Attorney

April 15, 2020

Ms. Shannon Anderson
Acting Director
Powder River Basin Resource Council
934 N. Main Street
Sheridan, WY 82801

Re: Review of Brook Mine Application – Rounds 8 to 12

Dear Ms. Anderson,

As you have requested, we have reviewed the relevant sections of the mine application and related documents for the proposed Brook Mine as it relates to mine subsidence potential and their effects and geotechnical reclamation issues. These materials include those prepared by Ramaco, WCC Engineering, Agapito Associates, Inc., Wyoming Department of Environmental Quality, and Engineering Analytics, Inc. A list of these documents reviewed for this report are provided in Attachment A.

The report covers Rounds 8 through 12. The 8th round submittal by Ramaco was mainly in response to the Wyoming Environmental Quality Council (EQC) comments who deemed the 7th application as inadequate for a number of issues. Rounds 9 to 12 submitted by Ramaco addressed further comments made by the Wyoming Department of Environmental Quality (DEQ). DEQ has determined the Round 12 mine application to be complete. Despite the Findings of Fact and Conclusions of Law by EQC, and having gone through 12 rounds of review with the Department of Environmental Quality, Ramaco only made a token effort to address the mine subsidence issues of the mine design. Because of the limited additional geotechnical information gathered by Ramaco, Ramaco's consultant Agapito Associates Inc. (AAI) of Colorado provides a Subsidence Control Plan (SCP) for only one seam and only the first area (TR-1) to be highwall mined, and even in this SCP analysis, there is a number of disclaimers/qualifiers to their findings. For example, AAI "DISCLAIMER:" … states … **"conclusions expressed herein are based on the facts currently available within the limits of existing data, scope of work, budget, and schedule.** Supporting data and information relied upon during the course of this investigation and used to prepare this report have been obtained from Ramaco Carbon records and files, available published reports and literature, personal communication with Ramaco Carbon staff, and other information sources. **Agapito Associates, Inc. makes no representation or warranty as to the accuracy of the data supplied and used in the development of this report"**(highlights added). This disclaimer is understandable given that only one additional hole was drilled and sampled with geotechnical testing for only one seam (the non-split Carney Seam). Yet, even with AAI's qualification for the design of only the TR-1 area (68 acres), Ramaco applies for in the application to allow highwall mining of a total of 1,960 acres with all, or the vast majority, of the land with proposed multi-seam mining.

It is acknowledged that Ramaco has hired a mining/geotechnical consultant, AAI, to address subsidence potential issues since the EQC's recent rejection of the Brook Mine application. AAI has provided responsive mine design analyses and associated subsidence potential analyses. These reported analyses, however, do not meet the necessary standard for review or provide sufficient assurances that significant subsidence will not occur from the highwall mining. Consequently, because there has been no substantive change in the Rounds 8 to 12 submittals, the main opinions provided in our report to you on January 23, 2017 have remained unchanged. The January 23, 2017 report is attached for your reference. See Attachment B.

A detailed review of the submitted AAI's report, the mining plan, the Subsidence Control Plan (SCP), and surface reclamation is given below.

PROPOSED MINING

The proposed highwall mining (HWM) methodology has been discussed in MEA, 2017. Since this report, the current application calls for the strip mining of the Monarch seam and no planned mining of the Monarch seam (MP1-2.2, MP.4.4, MP.4.4.1, and MP.4.6). In other words, only the Carney Coal is planned to be underground mined at this time. Another significant change from the Round 7 application is the abandonment of the most eastern highwall mining area, formerly TR-1 (see Figure 4.3, MEA, 2017). As pointed out by MEA during Round 7, HWM in this area was not well thought out. It contains significant mine spoil from previous Big Horn strip mining operations, and consequently, was not practical.

The new proposed HWM TR-1 area consists of only one block (in lieu Blocks 3 and 4 formerly TR-2, see MEA, 2017). The new mine plan is shown in Figure 2. Comparing Figure 4.3 (MEA, 2017) to Figure 2, it appears the changes in the mine plan only pertain to the old TR-1 and TR-2 areas. Consequently, the HWM areas which were Blocks 9 and 16 in Figure 4.3 still abut against old workings with minimum barrier coal of 0 to 70 ft. and consequently result in potentially flooding from the old workings to the south especially considering the likely inaccuracies of the mine map of the old works. Based on historical mapping, the floor depths in the minimum barrier areas are about 87 to 115 ft. in the new TR-4B, 5, and 7 areas. See Figure 2. Based on various empirical relationships on the minimum confirmed barrier thickness, this barrier should be at least about 55 to 110 ft. (Koehler and Tadolini, 1995), and therefore all areas (TR-4B, 5, and 7) would exceed the minimum confirmed barrier width depending on what criterion was used. Moreover, MSHA requires a minimum coal barrier width of 200 ft. for underground mining next to abandoned workings (30 CFR 75.388).

The general information on the room and pillar dimensions and panel, and coal barrier widths has remained unchanged. Only for new TR-1 area was more specific HWM design criteria proposed for the unsplit Carney Seam. For the maximum recommended extraction with a mined coal height of 14 ft. (Add. MP-6-42) and room width of 11.5 ft. (Add. MP-6-36) AAI determined the following (Add. MP-6-47).

Panel	Design Depth	Web Pillar Width	Panel Extraction	Tributary Pressure
1	266 ft.	14.1 ft.	45%	544 psi
2	279 ft.	14.2 ft.	45%	571 psi
3	333 ft.	17.9 ft.	39%	614 psi
4	338 ft.	18.3 ft.	39%	623 psi

AAI, however, assumed that only the Carney Seam will be mined in TR-1. For the TR-1 area, both the overlying Monarch and underlying Masters coal seams have mineable thicknesses (see Table 4.1, Block 4, MEA, 2017). Even though these seams are not currently planned to be underground mined, no comment was made by AAI on design of multiple seams. It should also be noted that no consideration is made in the design for the pillar loading imposed by the planned stockpiles of mine spoils depicted in the Exhibit MP.1-2. This exhibit shows the stockpiles to be as wide as about 500 ft. and as long as about 1,500 ft. These stockpiles could reach significant heights with no restriction.

GEOTECHNICAL DRILLING AND TESTING

The proposed geotechnical drilling and testing after Round 7 for the proposed future underground mining areas has generally become less stringent and more ambiguous as modifications were made to the permit application by Ramaco. In its final form, Ramaco states “in future highwall mining blocks outside the study (TR-1) area, additional hole(s) covering a similar area are appropriate, with a similar suite of tests” ... in the roof, coal and floor of the Carney Seam as has been performed in the TR-1 panel (Ramaco Responses to Round 8 DEQ Memorandum of Deficiencies dated January 14, 2019). Ramaco further stated in the permit application that “prior to initiation of auger mining activity, samples will be collected and strength testing will be conducted … in order to satisfy the requirements of the MSHA ground control plan which must be approved prior to mining.” These test results and analysis “will be provided to WDEQ/LQD” prior to mining.

In Appendix D5 – Topography, Geology & Overburden Assessment dated 12/19 prepared by WWC Engineering, it states tensile strength results will be used to size web pillars and barrier pillars to achieve SF set by MSHA ground control plan to conduct mining and minimize the risk of subsidence.

Below are the issues related to the above proposed geotechnical drilling and testing in the mine application.

1. The one geotechnical boring which was done in the TR-1 area, which is 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 areas or, for the matter, all of TR-1 appears inappropriate.

2. The promised number of geotechnical test holes and testing on what strata per HWM area is vague and undefinable as given in the above statements and in the application. Therefore, these geotechnical promises are not enforceable.

3. Specific types of geomechanical testing are given but they will provide a deficient assessment of long-term strength and should include the consolidated drained triaxial tests which were originally promised after Round 7. Also, no Atterberg Limits are stipulated which really assist in rock classification, the potential for softening, and softened strength parameter values.

4. Use of the tensile strength for determining the pillar strength by Ramaco as noted above is not appropriate and should not be allowed.

5. The exploration and testing program proposed in the mine application assumes only the Carney seam will be mined without any geotechnical provisions if multi-seam mining were to occur in the future.

6. DEQ should regulate the number of holes and testing required, not the mining company. Undefinable information supplied by Ramaco where future data and analysis are promised at an undetermined time prior to mining and without noted approval of a SCP by DEQ. Moreover, the data and analyses promised are related to MSHA requirements which are not focused on surface subsidence above HWM areas.

MINE STABILITY ANALYSIS

Ramaco's Approach

In response to EQC's Finding of Facts and Conclusions of Law – Round 7, Ramaco cites "Brook plans to do the necessary engineering work Dr. Marino suggests as part of the ground control plan Transcript – Barron testimony, pp. 1532-1533 (Comment EQC 60 – Round 7)". This was not done. The main concern is the assessment of the long term stability of the mine design analysis to prevent mine subsidence. In an effort to ensure that the "necessary engineering work" was done, long term stability design guidelines were provided and for convenience are provided in Attachment C. Instead, Ramaco ignored significant portions of these guidelines. Ramaco hired and directed AAI to perform design analyses for mining of one seam in one area (TR-1), see Figure 3. AAI utilized in design only one test hole in the TR-1 area with insufficient testing. Using this provisional design, however, Ramaco applied for a permit to mine the whole proposed mining area. The area of HWM of one seam that AAI provisionally designed for was about 68 acres compared to a total of about 1,960 acres of HWM applied for. Since no engineering analysis was performed for the multi-seam HWM condition, the submitted mine plan was absent of any criteria on the allowable thickness of the interburden for the different lithologic and mining conditions.

Because AAI's design report is incomplete in many respects, a complete critical expert review was not possible. This includes:

- No codified rock classification for understanding material types.
- Point data not provided for Carney Coal Thickness with contours of 0.5 ft. (see AAI Figure 3).
- Point data not provided for Carney Coal floor elevations with contours to 1.0 ft. (see AAI Figure 4).
- AAI states: "Unmapped faults may exist that complicate the seam structure" (Add. MP-6-24), but are not addressed in the design.
- Joint (fracture) pattern assumed in UDEC modeling used to check for mine instability not given (Add. MP-6-55).
- Joint slippage properties assumed in UDEC modeling used to check for mine instability not given (Add. MP-6-56).
- No reference for the assumed "western coal" strength.

- No long term strength data for the mine roof or floor.
- No analysis provided on how the floor stability was determined to be adequate (Add. MP-6-38,39).

In the analysis below, the fine-grained rock overburden and floor in the test hole (Boring 2017-4) done for the design of the TR-1 HWM area are classified as mudstone and is assumed as such in AAI stability analysis. It is unreasonable, however, to assume a roof and floor containing mudstone as the worst case condition when there is a significant amount of roof and floor material described as claystone in the other borings submitted in the application, especially without running, at a minimum, Atterberg Limits to verify the rock plasticity. These fine-grained clastic rocks are very difficult to properly identify without this testing (Marino and Osouli, 2012).

Below is the review of limited AAI mine design analyses against mine roof, pillar and floor failure based on the information available in the AAI report. See Figure 3.

<u>Roof Stability Design Analysis</u>

For the TR-1 area, AAI analyzes the mine roof short term stability for highwall mining. Because of the reported weak mudstone beds, AAI recommended leaving 1 ft. of coal in place to avoid short term collapse of the more immediate roof rock, although the more immediate mudstone is likely to collapse in the long term. AAI calculated a roof stand up time of only 77 days (Add. MP-6-38). AAI noted, however, that above the 6 ft. of strata of essentially mudstone sequences is a "18+ ft.-thick sequence of moderately strong sandstone that may be sufficiently competent to bridge across the 11.5 ft. opening width." In view of the reported overburden geology across application area as discussed in MEA, 2017, these sandstone beds are laterally discontinuous and thus, should not be relied upon as being omnipresent. Furthermore, evidence that sandstone is sufficiently present with adequate capacity in the overburden is not borne out by the massive amount of pit subsidence over the adjacent old works which are in the Carney Seam (see MEA, 2017).

<u>Pillar Stability Design Analysis</u>

For HWM in TR-1, AAI offers two designs: one with a stability factor (SF) of 1.6, and another where SF is 1.8 "to reduce the likelihood of pillar failure" (Add. MP-6-39). SF is calculated using the program ARMPS-HWM. This design methodology was developed for bituminous coal fields with web pillar heights of 7 ft. or less. The application conditions, however, fall outside this criteria. The Carney Seam is sub-bituminous coal and is 16-17 ft. thick in the TR-1 area reaching 18+ ft.-thick across the application area (see Table 4.1, MEA, 2017).

As stated by AAI, "Mark and Barton (1997) concluded that laboratory test results (typically from tests on 2-3 in. core) are a poor predictor of in-situ pillar performance, and that a constant in-situ coal strength of 900 psi (when considering 36" or greater cubes of inplace coal) produce better results" (Add. MP-6-40). However, AAI correctly recognized, as noted in MEA, 2017, that bituminous coal would have a higher strength than the Carney sub-bituminous coal. Therefore, AAI assumed in-situ coal strength of 762 psi. Rationale to arrive at 762 psi, however, defies logic. AAI justified the reduction from 900 psi to 762 psi for sub-bituminous coal based on the reduction of an unsubstantiated laboratory compressive strength for "western coal" to that for the Carney Seam (from Test Hole 2017-4). Yet by their own admission, lab tests do not relate to the larger in-situ cube strength. In addition, it is not known if the "western coal" strength was from bituminous or sub-bituminous coal or how it was derived. Moreover, AAI then claims the derived strength of 762 psi is "more conservative" without explanation (Add. MP-6-40).

Roof/Floor Bearing Design Analysis

AAI describes the immediate 6 ft. of the Carney roof as weak carbonaceous mudstone to mudstone which becomes sandy towards the top (Add. MP-6-33, 75-77). The carbonaceous mudstone was found to be non-durable with Slake Durability Index (SDI) of only 11.8% (Add. MP-6-32). As noted above, AAI calculated this roof's "stand up time" to be 77 days. Because of the concern for fallout during mining, however, AAI recommended leaving 1 ft. of sub-bituminous coal in the roof. However, whether or not this coal thickness can be remotely controlled or maintained if the coal thins or undulates, and how long the coal (without bolting with mesh) will remain are suspect. Caving in the long or short term of the weak immediate roof adversely affects the roof's ability to laterally restrain these mudstone strata above the pillar from roof squeeze. Based on the pillar design at SF=1.6, web pillar width to weak roof thickness ratio ($\frac{W_p}{h}$) would range from 2.35 to 3.0 for Test Hole 2017-4, and would be clearly susceptible to roof squeeze. No roof bearing analysis was performed by AAI.

The upper almost 2 ft. of the floor is described as carbonaceous mudstone which AAI states "is not expected to provide adequate floor conditions in a wet environment." This non-durable immediate floor had a reported SDI of only 22.4% with a very high natural moisture content of 18%. This material is underlain with at least 14 ft. of mudstone which is described as "weak, plastic mudstone which would form a very poor floor." This rock tested to be fairly non-durable with SDI's of 59.7% and 71% and with a high natural moisture content of 12.8%

(Add. MP-6-32-33)[1]. At the termination of the test hole, these mudstone sequence was at least about 14 ft. thick.

AAI also recommended leaving 1 ft. of sub-bituminous coal cover as a result of their concern for the floor conditions. This may assist in the immediate short term with HWM trafficability, if it can be done, but provides little benefit over time to restrain floor heaving. Given these floor conditions, $\frac{W_p}{h}$ is no greater than 1.3 for Test Hole 2017-4 and thus clearly more susceptible to pillar punching.

As noted above, AAI recommended the use of 1 ft. of roof and floor coal in their report. However, they later stated in response to a DEQ Deficiency Letter (Ramaco response to DEQ Memorandum dated December 27, 2018 by R. Barney) that the need for this roof and floor coal was not expected to be the normal condition. Consequently, an extraction height of 16 ft. should be considered in lieu of 14 ft. in the TR-1 area. Therefore, AAI analyses which assume an extraction height of 14 ft. are not most representative of what is expected in the TR-1 area.

AAI only performed a bearing capacity analysis on the mine floor. AAI stated "the bearing capacity stability factor of the CMS (carbonaceous mudstone) floor layer was calculated to be greater than 2" (Add. MP-6-39). AAI appears to erroneously ignore any failure through the underlying "weak, plastic mudstone." Moreover, no details of this important analysis are provided for review. However, it is stated that the bearing capacity analysis was done considering the cohesion and internal friction angle values for each layer as given in AAI Table 8. For the floor materials, AAI assumed cohesion and friction values of 243-553 psi and 20.9-29.2° respectively.

From our experience with mudstone floors, the strength values assumed by AAI for the fully softened and unsoftened conditions are too great (Marino and Osouli, 2012). AAI described these mudstones being weak and plastic yet while the friction angle values are reasonable, these assumed cohesion values, which are the dominant factor in determining the AAI calculated bearing capacity are too high. In fact, from a significant amount of testing we have done, the cohesion can drop to essentially zero in the fully softened state leaving only friction to resist bearing failure[2]. In the softened state, the bearing capacity of the non-durable mine floor with initial moisture contents of about 13% (as reported by AAI) can be easily below the design pillar pressures of 544 psi to 623 psi noted above. Moreover, it is unknown how these strength parameter values were specifically extrapolated by AAI since

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[1] From our experience, given a reported material moisture content of about 13% these reported SDI appear high.

[2] Although the extraction ratio proposed by AAI is below 50%, significant softening is expected below the web pillars because they only reach widths of about 18 ft. and $\frac{W_p}{h}$ is no greater than 1.3

they were not directly measured from any reported laboratory tests performed yet very specific. And, it is unknown why AAI only considered shearing in the top 1.8 ft. of carbonaceous mudstone (Add. MP-6-39) and ignored deeper seated failure into the “weak, plastic mudstone,” which is likely the more critical condition.

In fact, the UDEC modeling used to “check roof and floor for stability, and detect other potential failure mechanisms” considered the mudstone floor to also have a tensile strength ranging from 76 to 89 psi per layer in addition to the unrealistic cohesion, thereby further increasing the floor strength and improving stability. Note, in the unreported bearing capacity analysis, AAI stated no tensile strength was assumed. Use of a tensile strength in unsoftened to softened mudstone floor is completely unrealistic and reduces any indicated instability results.

As can be seen from the above, AAI using unreported bearing capacity methodology, arrived at acceptable floor stability using unrealistic floor strengths even in the unsoftened state. AAI did not consider the much weaker moisture softened condition despite moisture deterioration potential indicated by their only durability tests.

This floor will most likely be exposed to groundwater as a result of a number of factors:

- Even if a 1 ft. coal cover is considered, groundwater will seep through exacerbated by cracking in the coal from any significant floor heave from pillar punching and swell of floor materials from exposure to moisture.

- Groundwater exposure from unmapped faulting or shear zones, roof collapse uncovering beds seeping groundwater, surface runoff through complete chimney collapse events and the HWM opening, and flooding from adjacent old works.

AAI reported “It is expected that aquifers are associated with the coal seam(s) and adjacent sandstones with intervening shales and clays inhibiting vertical movement. Some groundwater inflows can be expected during highwall mining operations” (Add. MP-6-24,25).

AAI also investigated the potential for “cascading pillar failure,” or in other words, the potential of an outward progressive failure from localized pillar crushing or compression. This was analyzed using a program called LA Model. This software calculates the transfer of stress to adjacent previously unyielded pillars through bridging (or arching) in the roof overburden. However, the LA Model does not account for roof/floor bearing deformations and therefore this analysis is not valid given the site conditions. Moreover, given the reported mudstone roof and floor, it is not reasonable to consider there is not significant yielding of roof/floor which affects the outward progression of pillar failure especially since the failure is most likely in bearing not in the pillar.

SUBSIDENCE ANALYSIS

Surface subsidence is an expression of an underlying mine collapse. Over room-and-pillar workings subsidence develops in the form of sinkholes (aka pits) and bowl-shaped depressions (aka sags over room-and-pillar mines). Pits and smaller sags are caused by chimney roof failure above a mine opening, whereas larger sags result from yielding of a number of pillars from outright crushing, or roof/floor deformation (see UPDATE 14).

Pit Subsidence

The potential for pit or chimney subsidence was evaluated by AAI for only the TR-1 area for highwall mining of only the Carney seam. AAI concluded "the risk of sinkhole subsidence associated with highwall mining at the Brook Mine is considered low, but cannot be dismissed entirely, particularly in the shallower cover areas near the box cut (or highwall)." This opinion was in part based on a study of pit development in Colorado performed by Matheson, 1990, who developed the following equation to estimate the probability of pit subsidence.

$$P=1{,}516\left(\frac{D}{H}\right)^{-4.0}\quad\left(\text{for }\frac{D}{H}\geq 6.3\right)$$

where: D = depth of floor of opening
H = mining height
P = probability of pit subsidence

This probability model by Matheson was not applied by AAI as the data relied upon for this model excluded the case data AAI used in their analysis for sinkhole development potential above the proposed Brook Mine. Consequently, the above equation is not applicable. AAI used Matheson's excluded Colorado case because it better represented the room-and-pillar conditions proposed at the Brook Mine. From the excluded case data of 82 observed sinkholes, AAI determined the 100% probability was when $\frac{D}{H}$ equaled 2.7. Also, the Matheson probability is somewhat a misnomer as it actually is based on the frequency of subsidence occurrences per unit area.

With the use of the Matheson case data, AAI determined the frequency of observable sinkholes per unit area for different mine depth ranges. AAI added similar results were obtained when examining the observable subsidence over the adjacent Carney, KOOL and Monarch mines to the Brook Mine. With the use of these depth related frequencies, AAI determined that 7 sinkholes may develop using the Matheson Model to a depth of 178 ft. and none should develop beyond this depth. This, however, is only for the TR-1 area where the extraction height was erroneously assumed at 14 ft. AAI also noted 7 sinkholes was considered a conservative estimate since the HWM entry width of 11.5 ft. of roof span, was less compared to the Matheson studied mined-out area.

In performing a "probability" analysis of estimated number of sinkholes in the TR-1 area, AAI adopts the Matheson $\frac{D}{H}$ model. However, in the Matheson reference used by AAI, the definition for D is mis-stated and thus, inappropriately applied by AAI in their sinkhole analyses. D is the depth to the coal seam or the overburden thickness as indicated to Figure 4 and Table 3 of Matheson, 1990[3]. Also, this definition of D does not intuitively make sense and is not traditionally defined that way. Moreover, given that the "normal condition" for TR-1 is <u>not</u> to leave coal in the roof and floor, H will be 16 ft. not 14 ft. as assumed. Therefore, Table 9 in the AAI report was redone using the appropriate values and is provided in Table 1. This is analysis results in a predicted 16 sinkhole (distinct subsidence) features compared to 7 estimated by AAI. For the remaining HWM application area, these calculations with assumptions by HWM panel are given in Tables 2 to 15. Using this chimney subsidence prediction methodology by AAI, 2,680 sinkholes (1.4 subsidence events/acre) are estimated over the entire proposed HWM area. With this number of events, it is clearly not an unplanned subsidence plan.

Even though the AAI chimney subsidence prediction method appears inappropriate and an excessive over-estimate on the frequency of events, it does not provide any confidence that future chimney subsidence is not problematic. Moreover, the risk of surface subsidence from HWM entry roof collapse should also account for the following factors.

1. The less distinctive chimney features or sags will not be noticeable from the aerial photography used in the AAI analysis count subsidence events. In other words, the subsidence count made by AAI would be only for the more dramatic features which can be seen from high elevation aerial images. It would not include all the smaller pits or smaller to larger sags or troughs. Therefore, the prediction of "probability" of chimney subsidence (pits and smaller sags) underestimates the frequency of subsidence events.

2. In the current application, the Monarch seam is no longer highwall mined. It is only planned to be surface mined throughout the application area (Figure MP-6.1-1). Based on Figures 4.3, 4.1, to 4.24 in the 2017 MEA Report. The Monarch seam is shown present in Mine Blocks 13, 17, and 20. Surface mining in these areas will remove at least up to 35 to 105 ft. of overburden, the vast majority of which is rock and will be replaced with mine spoil. The reduction of the rock overburden in these

[3] D is mis-defined in the text of the paper. Note, if D were taken as floor depth, the overburden thickness to mined height would not be 2.7 at < 25 ft. depth.

areas with clayey mine spoil will clearly increase the risk of surface subsidence from HWM entry collapse from the underground mined Carney.

3. AAI chimney subsidence analysis does not account for the "portal" subsidence at the tapered back highwall. Also, data on how closure of the HWM openings will be addressed is not provided, for example, will the mine spoil be merely dumped in front of these HWM openings, as implied.

4. The method of "probability" used by AAI given above for sinkhole subsidence for HWM of the Carney seam in the TR-1 area is also in conflict with the methodology provided by Ramaco in the Subsidence Control Plan (SCP) for the overall application area. This methodology is discussed in detail in MEA, 2017. The methodology used by Ramaco recognizes the importance of other parameters in prediction of chimney subsidence which is ignored by the "probability" criteria used by AAI. Chimney prediction methodology (e.g., Piggott and Eynon, 1977, Garrad and Taylor, 1988, Whittaker and Reddish, 1989, and Dyne, 1998) typically considers at a minimum the bulking (volume expansion) from the caving of intact roof rock, the extraction height, width of intersecting mine openings and the repose angle or the spread of the caved material into mine openings. This was exemplified by Ramaco in Figure MP-6.2-4 (see Figure 4).

Sag Subsidence

AAI states that "the highwall mining plan (for the Carney seam in the TR-1 area) for the Brook Mine has been developed to minimize the likelihood of trough (sag) subsidence"… (Add. MP-6-62). As noted above, sag subsidence from pillar bearing failures into the "weak" "plastic" mudstone floor (and possibly roof) appears likely. This type of failure would cause sag or trough subsidence in addition to smaller sags from chimney subsidence. From a study performed by the USGS in the project area, Dunrud and Osterwald 1980 illustrated both trough and pit subsidence from the area, which is shown in Figure 5. Note, the USGS illustration depicts pit/sinkhole subsidence inside a larger sag. This indicates at shallower depths where sinkholes occur, massive pillar related failure would also occur. In addition to outright crushing, pillar failure can be induced by excessive deformation in the weak adjacent mudstone. Moreover, AAI notes that pillar failure can cause spontaneous combustion (Add. MP-6-21). Coal fires are not uncommon in the area and can result in additional subsidence and possibly other environmental concerns. Moreover, in review of the mine application, the Wyoming Land Quality Division (LQD) noted in a Memorandum dated December 27, 2018 that "leaving coal in the roof and the floor (as proposed by AAI above) there may be increased chance for spontaneous combustion of coal and coal fires. Coal fires could potentially weaken pillars."

SUBSIDENCE REMEDIATION

In the mine application, Ramaco discussed their remediation plan if chimney (sinkhole) subsidence would result over the proposed HWM area. Ramaco stated that areas highwall mined will be "monitored for at least 6 months after highwall mining of the individual areas are completed. If there is no evidence of subsidence, then the monitoring of the area will be discontinued" … "Backfill" of the detected subsidence will however only be "performed on a selective/as-needed basis." The select subsidences which will be remediated will be only those which do not exhibit "self-healing" and there is the introduction of oxygen or surface water. Ramaco notes it "will continue to perform remediation on any subsidence, detected during or subsequent to the 6 month monitoring period, until bond release is approved" (MP-6.3 and MP-6.4).

The above remediation plan does not require any monitoring above HWM areas beyond 6 months, and only remediates those which are not "self-healing" in lieu of remediating all sinkholes. Moreover, "self-healing" is not sufficiently defined. If the sinkhole collects water, would that mean it has "self-healed"? In lieu immediately "backfilling" the pit, is there a waiting period to determine if it will "self-heal"? It is also unclear how the pit will be backfilled.

From our experience, at a minimum, backfilling a subsidence event in an open field should include compaction of the subsidence bottom and then compaction of the subsequent lifts of select fill placed in depression. The backfilling should continue to at least meet the natural surrounding surface contour, and as noted in the application, be covered with topsoil that supports the vegetation demand. Although not even considered in the Ramaco SCP, remediation should also apply to trough or sags which have significant depth affecting surface drainage.

It should be noted that the Ramaco subsidence remediation plan falls way short of the reclamation efforts performed by the State on the subsidence features which have resulted above the adjacent abandoned Carney Mine No. 44 (PHC Reclamation, 2006).

Criteria is recommended by AAI for "any surface structures or other facilities" that would require protection from subsidence for HWM. Their report states "AAI considers a 50 ft. offset and an angle of critical deformation of 25° to be appropriate." Under the most likely site conditions, this criteria appears to be acceptable.

SURFACE RECLAMATION

In Section RP.3.3 entitled Post Mine Slope Analysis, the reclaimed land slopes are reported from 0 to greater than 45° and are in fact, noted to 69.5° (Table RP.3-1) without distinction of which slopes are native or reclaimed. It is not known whether the greater slopes are in native rock or highwall areas, or native or reclaimed soil slopes. Further, there is no discussion of how the reclaimed slope will be constructed to prevent landsliding conditions, or analysis of the stability of such slopes. Given that the majority of the mine spoil will likely consist of rubblized claystone, only gentle slopes should be tolerated.

DEQ OVERSIGHT

In Round 7, DEQ admitted it has only limited expertise in mine subsidence engineering. This explained the blatantly inadequate review of the subsidence engineering aspects of the Brook Mine Application. In lieu of soliciting an expert in mine subsidence, the agency had in effect acted as a "pass through" in determining that the application was technically complete in this respect.

Recognizing that they did not have sufficient expertise to evaluate the subsidence engineering aspects of the Brook Mine application, after Round 7 DEQ contracted with Engineering Analytics, Inc. (EAI). Engineering Analytics scope of work was "to provide an evaluation of a subsidence sampling and analysis plan" of the Brook Mine Submittals and to provide "evaluation of the adequacy of Brook Mine's submittal in addressing each subsidence finding in the EQC order" (EAI Technical Memorandum dated June 19, 2018 and DEQ Memorandum dated October 16, 2018).

Accordingly, Mr. Dan Overton of Engineering Analytics notes in a Technical Memorandum dated June 29, 2018 that the EQC recommended "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)". These suggestions and concerns were spelled out in the 2017 MEA Report (see Attachment B) and the document entitled: Room and Pillar Recommendations Against Surface Subsidence – Proposed Brook Mine, Sheridan, Wyoming (see Attachment C) and in an initial review of items from the Round 8 application provided to DEQ in an email dated December 31, 2018. The MEA report and recommendations documents were in the possession of the DEQ in addition to the EQC prior to their written order. Based on the review of the most recent Brook Mine application documents, which was deemed complete, our concerns provided in these above documents were substantially ignored. Furthermore, there is no evidence, other than possibly MEA 2017, that these documents were even received or considered by Engineering Analytics, despite EQC findings. Note, there is no reference to any of these documents in any of EAI's reports.

From review of their Technical Memorandums on the Brook Mine submittals related subsidence issues, Engineering Analytics performed no independent critical analyses of the mine design and associated subsidence potential as performed herein. The vast majority of the EAI Technical Memorandums are a regurgitation and explanation of Ramaco's submittals. However, EAI properly identified the use of consolidated drained triaxial tests in one of the earlier reviews (Technical Memorandum dated June 29, 2018). In this earlier memorandum, EAI states the Brook Mine "subsidence sampling plan is not sufficient as presented" and their plan "remains deficient" in all subsidence related phases. Given the subsequent responses by Ramaco, it is unclear how these major issues were resolved.

Moreover, DEQ provides no geotechnical guidelines or requirements for mine subsidence engineering, such as: minimum required drilling and testing requirements, design methodology, minimum safety or stability factor criteria, protection requirements against subsidence for surface infrastructure, and minimum subsidence remediation requirements. In fact, without such constraints, DEQ had accepted Ramaco explanation that the mine design "will be done in due time."

In terms of subsidence remediation and surface reclamation, DEQ accepted vague and minimal subsidence remediation and reclamation standards. These subsidence standards are far below even the State's own standards as evident by the subsidence reclamation efforts by the State conducted above the adjacent abandoned Mine No. 44.

SUMMARY AND CONCLUSIONS

The findings from this investigation are provided below.

1. Ramaco Resources, Inc. has submitted several rounds of application for the Brook Mine (Rounds 8 to 12). Despite the Wyoming Environmental Quality Council (EQC) comments regarding the technical deficiencies in the applications associated with the subsidence issues of the application from Round 7, Ramaco responded with merely a token effort to address EQC's concerns.

2. Through their consultant, Agapito Associates, Inc. (AAI), Ramaco provided in their Round 8 application more specific mine design criteria for a highwall mining (HWM) of about 68 acres for one coal seam while applying for a total of 1,960 acres of HWM mining. Even their consultant, AAI would not extend their provisional design (with disclaimer) beyond the 68 acre area and just for the unsplit Carney seam with only one new test hole done in supposedly the 68 acre area.

3. Because of lack of specificity, it is unclear how extensive the geotechnical exploration and testing will be, but it clearly lacks long-term stability assessment investigation.

Also unidentifiable, are the types of future mine subsidence engineering analyses that will be performed, and when they will be submitted to DEQ for future HWM areas.

4. In the design analysis, AAI treats the anomalous conditions in one test hole to be uniformly applicable across the entire 68 acre HWM design area. These anomalous conditions depicted in the one test hole and relied upon, may be the cause for AAI disclaimer on their recommendations. In this test hole, the most critical roof/floor conditions are described as mudstone compared to all the other drilled holes in the application which report the presence of claystone – which is considered a more unstable material.

5. Ramaco and AAI do not adequately address the long-term instability of the proposed mine workings that could lead to subsidence. Ramaco and AAI do not account for the significant deterioration of at least mudstone roof and floor materials when exposed to moisture despite their own testing indicating such. In places, the design analysis lacked specificity and thus cannot be critically reviewed. For example, a more critical element of mine instability, which could lead to surface subsidence, are roof/floor bearing failures. AAI only reported a safety factor against failure of only the immediate mudstone floor without any calculations. Further, there was no analysis by AAI of roof bearing failure in the weak mudstone.

6. AAI determines for the TR-1 area that 7 distinctive subsidence features (aka sinkholes) may occur of this HWM area. After correction of this calculation this amount is more than double and over 2,000 such events are expected over the entire proposed HWM area using this methodology.

7. The proposed subsidence remediation by Ramaco in the application is ambiguous and allows for the possibility of many resulting subsidence events to remain untreated. This proposed subsidence remediation plan falls way short of the State's own reclamation standards. Moreover, the surface reclamation plan contains no slope stability analysis despite the steep proposed slopes.

8. With insufficient expertise in mine subsidence engineering, the Department of Environmental Quality (DEQ) has acted as a "pass through" agency through Round 12 and has contracted with Engineering Analytics Inc. (EAI) to review these aspects of the mine application after Round 7.

9. Based on the review of correspondence, DEQ did not provide their subsidence consultant EAI, MEA's suggested guidelines for room-and-pillar design against

subsidence for review (see Attachment B) and other MEA material to the application. The consultant subsidence did not include any significant critical analyses of the submitted application materials.

10. As noted above, the permit application only addresses the highwall mining of the 68 acres of Carney Seam. With application approval, this may provide an administrative mechanism for DEQ to approve remaining underground mining of other mineable seam areas without proper public oversight via a non-significant revision to the permit. This would involve the entire 1,960 acres of proposed highwall mining.

    At a minimum, it is recommended that any highwall mining be removed from the permit until it is reasonably investigated in order not to setup such a precedent of unacceptable protocols. HWM areas should be applied for increments as Significant Revisions as proper subsidence engineering investigation is accomplished. Moreover, in the first 5 years on operation the Brook Mine intends on only surface mining with no highwall mining. This is also consistent with Ramaco's statement in the application that the permit will be renewed every 5 years (Mine Plan prepared by WWC Engineering dated 12/19). Another reason why the HWM application should be delayed and become a Significant Revision is the statement by Ramaco … "AAI agrees that reevaluation should be considered if the ultimate plan involves a greater cutting width, height, or penetration or a lesser production rate than assumed" (Ramaco Response to Round 8 DEQ Memo of Deficiencies dated January 9, 2018).

QUALIFICATIONS

MEA is a leading expert in subsidence engineering from underground mining and from karst. For over 40 years, MEA's staff have provided services across the full scope of subsidence engineering, including significant work in research, site subsidence studies, mine stability design, failure analyses, prediction of subsidence displacement and damage potential, subsidence damage evaluation, foundation design, repair design, and grout stabilization design and monitoring. Being foremost in this field, MEA staff has authored over 100 publications on related topics and have worked in ore fields and karst across the U.S. and Canada. MEA's experience extends to underground mines in limestone, gold, trona, salt, lead/zinc, iron, and coal. Because of our broad reach, MEA is licensed to practice in 27 states.

MEA has also been hired by mining companies and others to provide consulting services on active or new operations for both room-and-pillar and longwall mining in addition to low to high extraction old works. These services are included in those listed above.

Because of the amount of coal mining related work MEA has done, it has designed and developed a cross-hole radar to detect mine voids for cases where mining may exist. Also, from our experience in karst, MEA has researched and developed a TDR system which can be used to detect incipient subsidence beneath a structure.

Having extensively worked on old workings and both low and high extraction active mines, MEA is uniquely qualified and separates itself from other geotechnical and mining engineering companies across the U.S.

If you have any questions about our review of the most recent Brook Mine Application, please contact us.

Sincerely,

Gennaro G. Marino, Ph.D., P.E., D.GE
President

ENCLOSURES:

REFERENCES

FIGURE 1	NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING COAL REMOVAL SEQUENCE
FIGURE 2	NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING THE ADJACENT OLD WORKS
FIGURE 3	SKETCHES OF THE THREE PRINCIPAL MODES OF FAILURE OF ROOM-AND-PILLAR MINE WORKINGS WHICH CAN RESULT IN SURFACE SUBSIDENCE
FIGURE 4	RAMACO ILLUSTRATION SHOWING THE VARIABLES INVOLVED IN DETERMINING CHIMNEY SUBSIDENCE
FIGURE 5	USGS ILLUSTRATION OF PIT AND SAG (TROUGH) SUBSIDENCE IN THE PROJECT AREA (DUNRUD AND OSTERWALD, 1980)
TABLE 1	REVISED AAI TABLE 9 SUBSIDENCE DATA FROM DEVELOPMENT – ONLY MINES – FOR TR1

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Dunrud, C. Richard., and Frank W. Osterwald, 1980. Effects of Coal Mine Subsidence in the Sheridan, Wyoming Area. Washington: U.S. Govt. Print. Off.

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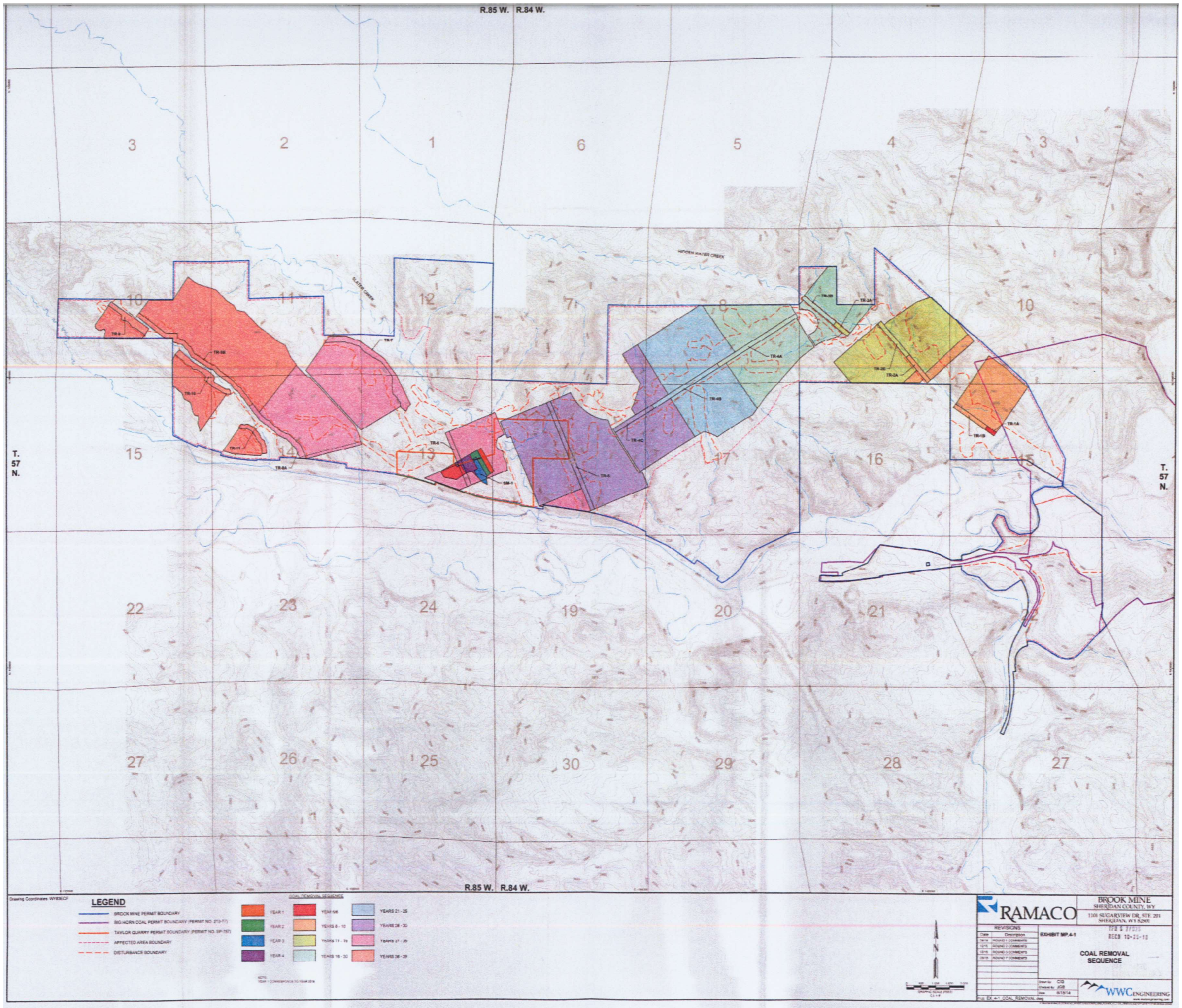


FIGURE 1 NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING COAL REMOVAL SEQUENCE

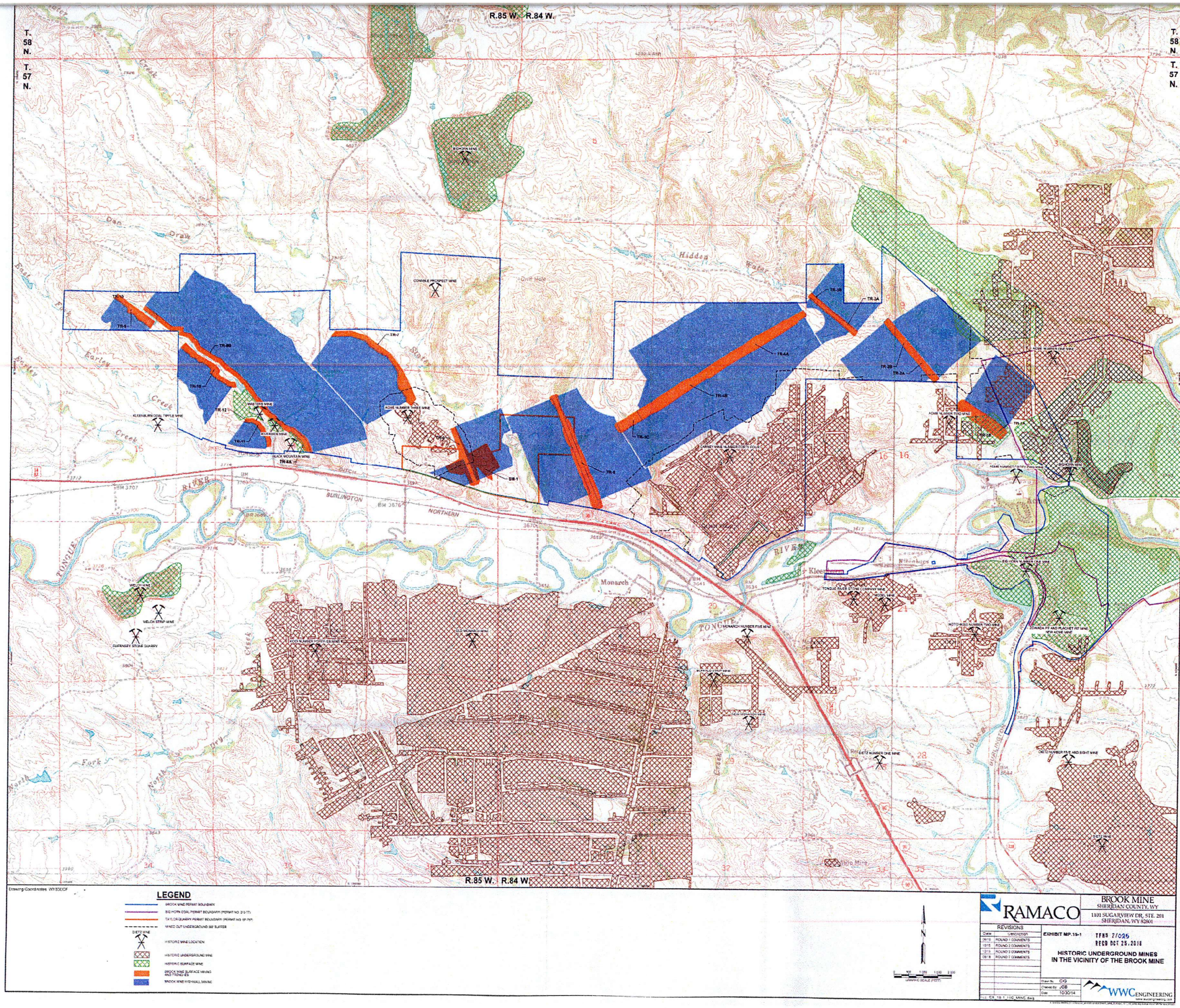
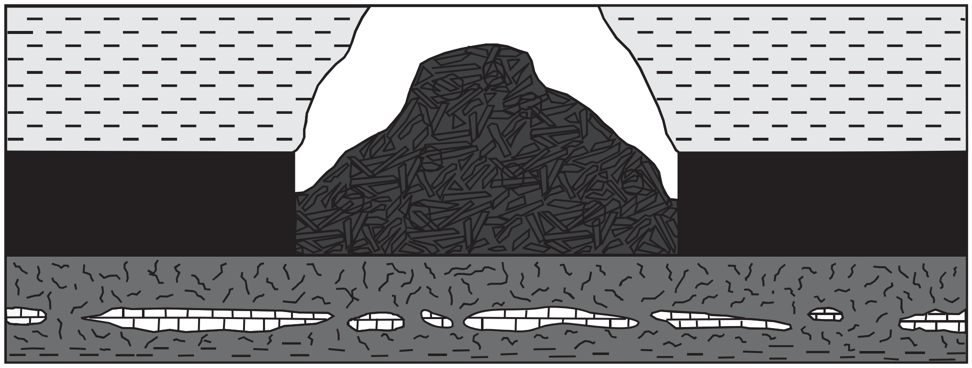
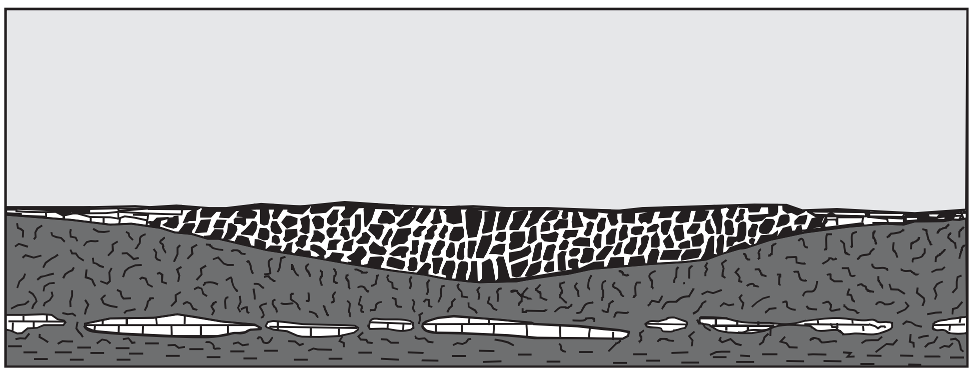


FIGURE 2 NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING THE ADJACENT OLD WORKS

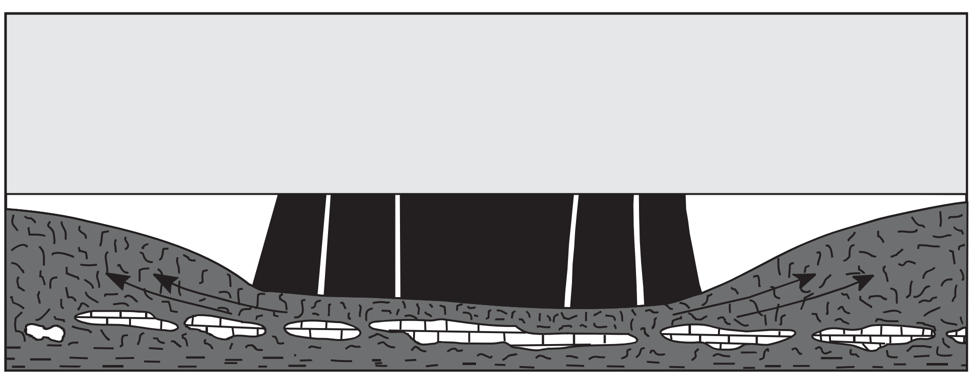
MEA



ROOF FAILURE ABOVE ROOM



PILLAR CRUSHING



PILLAR PUNCHING

FIGURE 3 SKETCHES OF THE THREE PRINCIPAL MODES OF FAILURE OF ROOM-AND-PILLAR MINE WORKINGS WHICH CAN RESULT IN SURFACE SUBSIDENCE

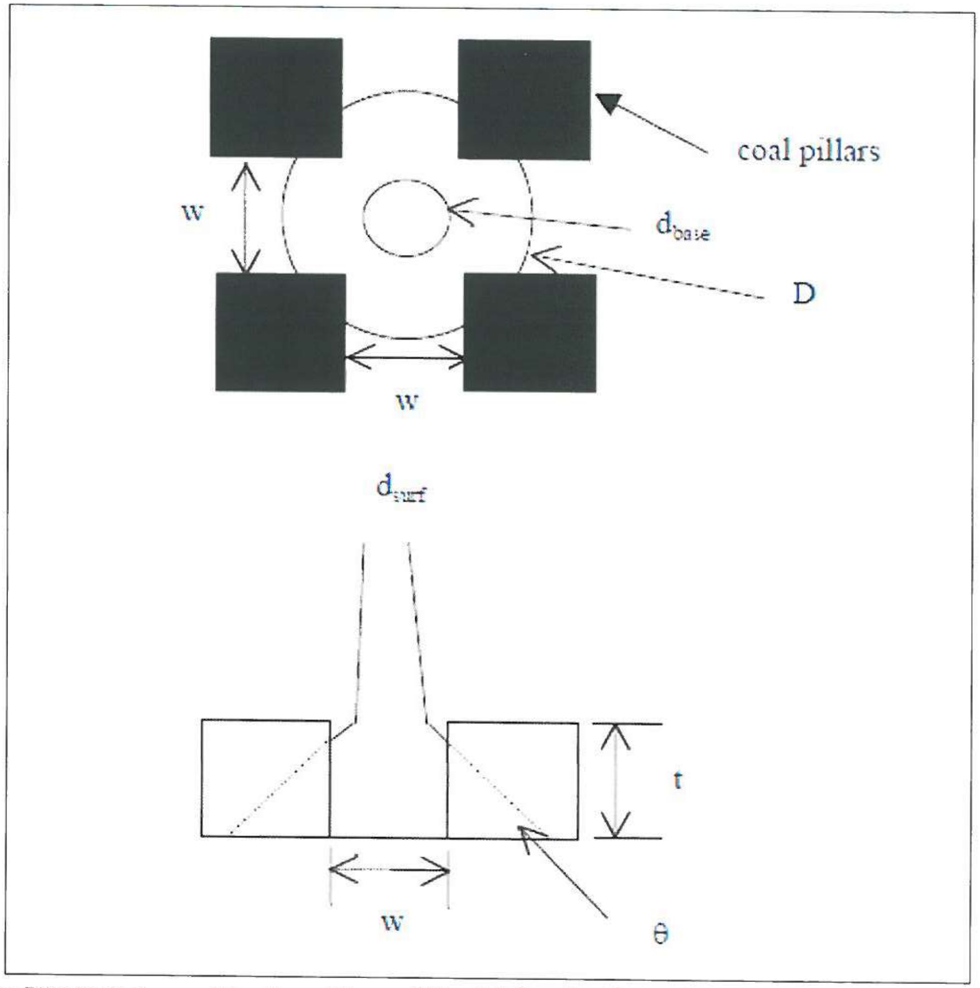


Figure MP-6.2-4 Explanation of Variables in Equation MP-6.2-1 (Dyne, 1998)

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FIGURE 4 RAMACO ILLUSTRATION SHOWING THE VARIABLES INVOLVED IN DETERMINING CHIMNEY SUBSIDENCE

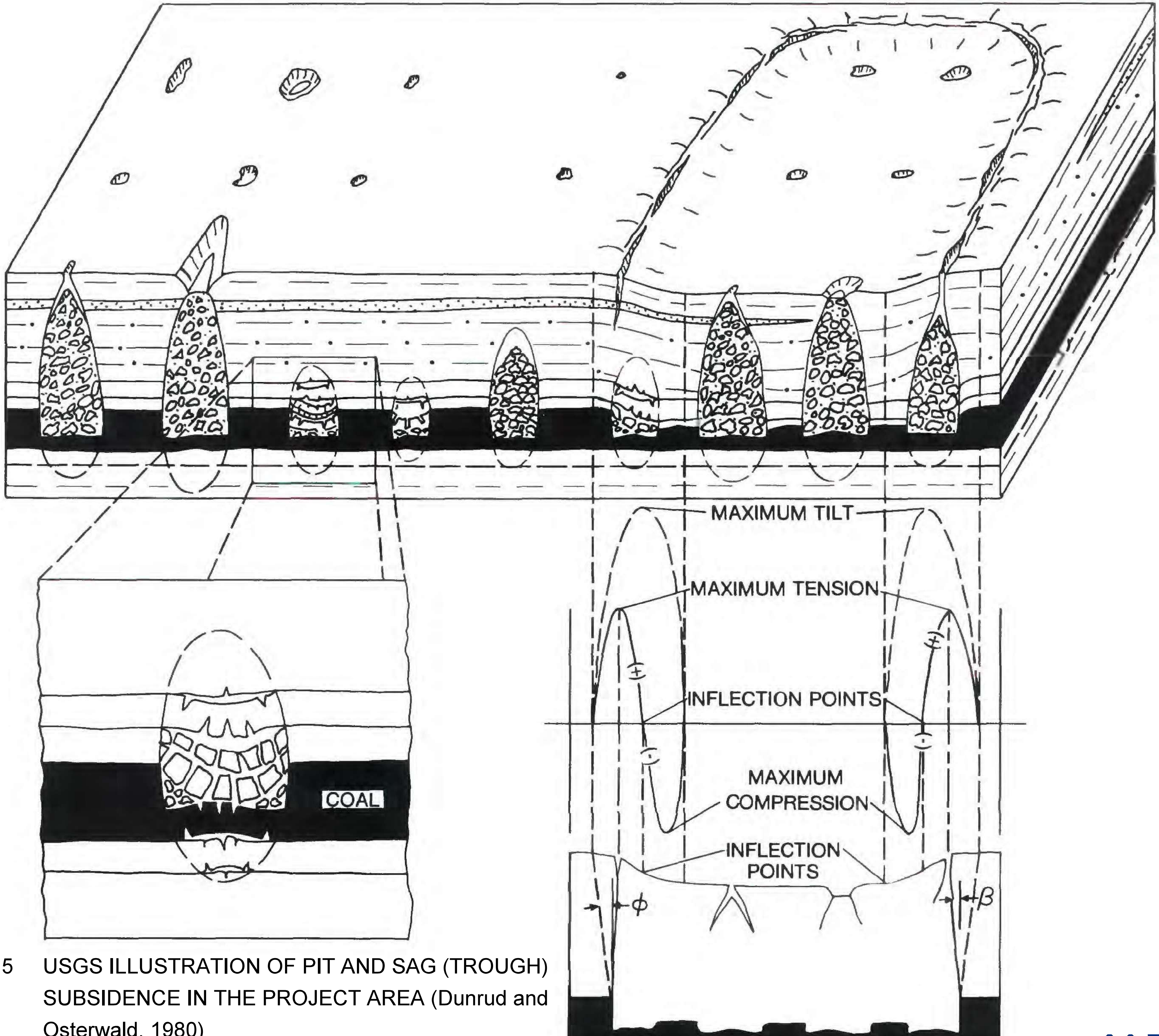

FIGURE 5 USGS ILLUSTRATION OF PIT AND SAG (TROUGH) SUBSIDENCE IN THE PROJECT AREA (Dunrud and Osterwald, 1980)

TABLE 1 REVISED AAI TABLE 9 SUBSIDENCE DATA FROM DEVELOPMENT- ONLY MINES- FOR TR1

Matheson Depth Range (ft)	Brook Mine Depth Range (ft)	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<25	<44	2.7	0.0	17.01	0.0
25-50	44-87	4.1	0.0	8.05	0.0
50-75	87-131	6.9	1.6	5.47	8.7
75-100	131-175	9.6	19.1	0.24	4.6
100-125	175-218	12.4	7.8	0.26	2.0
125-150	218-262	14.6	7.0	0.06	0.4
150-175	262-306	17.9	21.0	0.00	0.0
				Total	16

Notes:
1) TR-1 encompasses Panel 4 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 16ft.

MEA

TABLE 2 CARNEY SEAM TOTAL ACREAGE PER DEPTH INTERVAL, AVERAGE THICKNESS AND MINIMUM THICKNESS

							Thicknesses				
Trench	Panel	Total Acreage of Panel	0-115ft Deep (Total Acreage)	115-154ft. Deep (Total Acreage)	154-178ft. Deep (Total Acreage)	Shallowest Carney is Present. (FT.)	Average Carney (FT)	Average Upper Carney(FT .)	Average Lower Carney (FT.)	Interburden between Upper and Lower Thickness (ft.)	Add to Overburden Contours
TR-1	4	72	0.8	15.1	4.6	110	16.5	NA	NA	NA	NA
TR-2	5	78	12.8	3.3	1	55	16.5	NA	NA	NA	NA
TR-2	6	103	15.75	10	11.65	50	18	NA	NA	NA	NA
TR-3	7	16	16	NA	NA	30	11.5	NA	NA	NA	NA
TR-3	8	43	25.2	7	4.4	15	15	NA	NA	NA	NA
TR-4	9	261	87.3	56.1	58.7	75	13.5	6	6.5	<2	NA
TR-4	10	210	21.6	36	34.7	60	11	6	4	<2	NA
TR-5	11A 11B	124	9.9	36.2	64.4	50	11.5 6	4.5	6	11A <2, 11B 4	11A NA, 11B 8.5
TR-5	12	123	28.8	13.6	29	35	14	4	9	<2	NA
TR-6	13	34	34	NA	NA	30	9	4	9	20	24
TR-6	14	2	NA	2	NA	140	9	4	9	36	40
TR-6	15	12	0.1	1.1	0.1	100	9	4	9	24	28
TR-7	16	131	131	NA	NA	40	8.5	5	8.5	10	15
TR-8	17	368	322.9	44.7	0.4	15	8.5	3.5	8.5	16	19.5
TR-11	18	19	19	NA	NA	10	4	2	4	11	13
TR-10	19	48	48	NA	NA	10	5	5	5	7	12
TR-9	20	22	22	NA	NA	35	4.5	3.5	4.5	9	12.5

Notes: Panels 1-3 have been eliminated from the mining plan.

Panels 4-8 are Carney seam,Panels 9 and 10 have the Carney and where it splits into Upper and Lower Carney, and Panels 11-20 are Upper and Lower Carney.
Panels 11 and 12 are primarily under 2ft difference, 11B is 4ft. Average difference.
For Panels 13-18 an average thickness of the interburden was used for these to determine the overburden depth.
For Panels 19 and 20 the borehole drilled in that area was used for the interval information.
Where coal seam splits are less than 2ft. both the upper and lower veins are considered mined with a 1ft. Thick split considered between the veins.

TABLE 3 ESTIMATED NUMBER OF SINKHOLES FOR PANELS 5 AND 6 FOR AVERAGE CARNEY THICKNESS

Panel Depth Range (ft)	Ratio of Depth to Thickness	Panel 5 Surface Area (Acres)	Panel 6 Surface Area (Acres)	Total Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<44	2.7	0.0	0.0	0.0	17.01	0.0
44-87	4.1	4.7	8.9	13.6	8.05	109.1
87-131	6.9	2.1	10.8	12.9	5.47	70.4
131-175	9.6	31.2	14.4	45.5	0.24	10.9
175-218	12.4	14.6	17.2	31.8	0.26	8.3
218-262	14.6	7.5	25.6	33.0	0.06	2.0
262-306	17.9	0.0	0.0	0.0	0.00	0.0
					Total	201

Notes:
1) TR-2 encompasses Panels 5 and 6 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 16ft.

TABLE 4 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 7 FOR AVERAGE CARNEY THICKNESS

Panel Depth Range (ft)	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<32	2.7	0.0	17.01	0.0
32-63	4.1	3.7	8.05	29.9
63-95	6.9	7.1	5.47	38.7
95-126	9.6	2.3	0.24	0.6
126-158	12.4	0.0	0.26	0.0
158-190	14.6	0.0	0.06	0.0
190-221	17.9	0.0	0.00	0.0
			Total	70

Notes:
1) TR-3 encompasses Panel 7 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 11.5ft.

MEA

TABLE 5 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 8 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<41	2.7	5.7	17.01	96.6
41-82	4.1	8.0	8.05	64.4
82-124	6.9	7.6	5.47	41.4
124-165	9.6	7.2	0.24	1.7
165-206	12.4	5.5	0.26	1.4
206-247	14.6	1.9	0.06	0.1
247-288	17.9	0.0	0.00	0.0
			Total	206

Notes:
1) TR-3 encompasses Panel 8 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 15ft.

TABLE 6 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 9 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<37	2.7	0.0	17.01	0.0
37-74	4.1	0.0	8.05	0.0
74-111	6.9	73.5	5.47	402.0
111-148	9.6	83.7	0.24	20.1
148-185	12.4	74.5	0.26	19.4
185-223	14.6	28.4	0.06	1.7
223-260	17.9	0.0	0.00	0.0
			Total	444

Notes:
1) TR-4 encompasses Panel 9 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 13.5ft.

MEA

TABLE 7 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 10 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<30	2.7	0.0	17.01	0.0
30-60	4.1	1.2	8.05	9.4
60-91	6.9	10.8	5.47	59.3
91-121	9.6	12.0	0.24	2.9
121-151	12.4	42.8	0.26	11.1
151-181	14.6	52.5	0.06	3.2
181-212	17.9	41.1	0.00	0.0
			Total	86

Notes:
1) TR-4 encompasses Panel 10 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 13.5ft.

TABLE 8 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 11A FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<32	2.7	0.0	17.01	0.0
32-63	4.1	0.0	8.05	0.0
63-95	6.9	2.3	5.47	12.6
95-126	9.6	9.0	0.24	2.1
126-158	12.4	14.2	0.26	3.7
158-190	14.6	38.0	0.06	2.3
190-221	17.9	0.0	0.00	0.0
			Total	21

Notes:
1) TR-5 encompasses Panel 11A based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 11.5ft.

MEA

TABLE 9 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 11B FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<16	2.7	0.0	17.01	0.0
16-33	4.1	0.0	8.05	0.0
33-49	6.9	0.0	5.47	0.0
49-66	9.6	1.4	0.24	0.3
66-82	12.4	0.8	0.26	0.2
82-99	14.6	0.9	0.06	0.1
99-115	17.9	1.1	0.00	0.0
			Total	1

Notes:
1) TR-5 encompasses Panel 11B based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 6ft.

TABLE 10 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 12 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<38	2.7	0.0	17.01	0.0
38-77	4.1	6.4	8.05	51.1
77-115	6.9	16.0	5.47	87.8
115-154	9.6	26.0	0.24	6.2
154-192	12.4	18.9	0.26	4.9
192-231	14.6	5.8	0.06	0.3
231-269	17.9	0.0	0.00	0.0
			Total	151

Notes:
1) TR-5 encompasses Panel 12 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 14 ft.

MEA

TABLE 11 ESTIMATED NUMBER OF SINKHOLES FOR PANELS 13, 14 AND 15 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Panel 13 Surface Area (Acres)	Panel 14 Surface Area (Acres)	Panel 15 Surface Area (Acres)	Total Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<25	2.7	0.0	0.0	0.0	0.0	17.01	0.0
25-49	4.1	0.2	0.0	0.0	0.2	8.05	1.8
49-74	6.9	2.0	0.0	0.0	2.0	5.47	11.1
74-99	9.6	6.1	0.0	0.0	6.1	0.24	1.5
99-124	12.4	2.4	0.0	0.0	2.4	0.26	0.6
124-148	14.6	0.7	0.0	4.2	4.8	0.06	0.3
148-173	17.9	0.0	0.1	3.2	3.3	0.00	0.0
						Total	16

Notes:
1) TR-6 encompasses Panels 13, 14 and 15 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 9 ft.

TABLE 12 ESTIMATED NUMBER OF SINKHOLES FOR PANELS 16 AND 17 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Panel 16 Surface Area (Acres)	Panel 17 Surface Area (Acres)	Total Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<23	2.7	0.0	0.0	0.0	17.01	0.0
23-46	4.1	2.5	58.4	60.9	8.05	489.9
46-70	6.9	79.6	58.4	138.0	5.47	755.0
70-93	9.6	37.4	59.6	97.0	0.24	23.3
93-117	12.4	11.5	79.8	91.2	0.26	23.7
117-140	14.6	0.0	61.9	61.9	0.06	3.7
140-163	17.9	0.0	29.7	29.7	0.00	0.0
					Total	1296

Notes:
1) TR-7 and TR-8 encompass Panels 16 and 17, respectively based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 8.5 ft.

MEA

TABLE 13 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 18 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<11	2.7	0.0	17.01	0.0
11-22	4.1	0.0	8.05	0.0
22-33	6.9	0.0	5.47	0.0
33-44	9.6	9.7	0.24	2.3
44-55	12.4	9.4	0.26	2.4
55-66	14.6	0.0	0.06	0.0
66-77	17.9	0.0	0.00	0.0
			Total	5

Notes:
1) TR-11 encompasses Panel 18 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 4 ft.

TABLE 14 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 19 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<14	2.7	0.0	17.01	0.0
14-27	4.1	0.0	8.05	0.0
27-41	6.9	23.2	5.47	127.0
41-55	9.6	9.3	0.24	2.2
55-69	12.4	11.8	0.26	3.1
69-82	14.6	3.6	0.06	0.2
82-96	17.9	0.0	0.00	0.0
			Total	133

Notes:
1) TR-10 encompasses Panel 19 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 5ft.

TABLE 15 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 20 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<12	2.7	0.0	17.01	0.0
12-25	4.1	0.0	8.05	0.0
25-37	6.9	5.6	5.47	30.9
37-49	9.6	3.5	0.24	0.8
49-62	12.4	6.6	0.26	1.7
62-74	14.6	3.3	0.06	0.2
74-87	17.9	2.6	0.00	0.0
			Total	34

Notes:
1) TR-9 encompasses Panel 20 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 4.5ft.

MEA

ATTACHMENT A

Documents Reviewed

Response to EQC Finding of Facts and Conclusions of Law, WDEQ Comments Round 7 – Brook Mine Permit to Mine Application TFN 6 2/025

Figure 2.3-1 – Carney Seam Pre-mine Potentiometry (Round 7 and Round 9)

Addendum MP-6 – Subsidence Control Plan (Round 7 and Round 9)

Addendum MP-6-11 (Round 8 and Round 9)

Addendum MP-6-12,13,14,15 (Round 7 and Round 9)

Attachment MP-6-A (Round 9)

Mining Plan (Round 8 and Round 9)

Table MP.1-3,4 (Round 7 and Round 9)

Figure MP.1-1,2,3,4,5 (Round 7 and Round 9)(MP.1-5 Removed in Round 9)

Figure MP.4-1,2,3 (Round 7 and Round 9)

Figure MP.2-1,2 (Round 9)

Figure MP.3-1 (Round 9)

Figure MP.9-1 (Round 7 and Round 9)

Mine Plan Exhibits (Round 8 and Round 9)

Index Sheet for Mine Permit Amendments or Revisions (Round 8 and Round 9)

Mining Plan Table of Contents (Round 8 and Round 9)

Exhibit MP.15-1,2 (Round 7 and Round 9)

Brook Mine_New Permit Application_CHIA 39_DRAFT_28Feb2020 (Round 12)

Reclamation Plan (Round 9)

Appendix D5 Topography, Geology and Overburden Assessment (Round 9)

Appendix D6 Hydrology (Round 7 and Round 9)

Addendum MP3 Hydrostatic Units (Round 7 and Round 9)

Brook RD10_Total Submittal_Combined (Round 10)

RAMACO_CARF_2019_GW_Elevations (Round 10)

RAMACO_CARF_2019_GW_Quality_Field (Round 10)

RAMACO_CARF_2019_GW_Quality_Lab (Round 10)

Round 8 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 8 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 9 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 9 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 10 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 10 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 11 Technical Review, DEQ Comments/Cover letter, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Cover Letter, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Submittal, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Comments Change Index, Brook Mine Coal Mine Permit Application, TFN 6 6/025

April 15, 2020

Ms. Shannon Anderson
Acting Director
Powder River Basin Resource Council
934 N. Main Street
Sheridan, WY 82801

Re: Review of Brook Mine Application – Rounds 8 to 12

Dear Ms. Anderson,

As you have requested, we have reviewed the relevant sections of the mine application and related documents for the proposed Brook Mine as it relates to mine subsidence potential and their effects and geotechnical reclamation issues. These materials include those prepared by Ramaco, WCC Engineering, Agapito Associates, Inc., Wyoming Department of Environmental Quality, and Engineering Analytics, Inc. A list of these documents reviewed for this report are provided in Attachment A.

The report covers Rounds 8 through 12. The 8th round submittal by Ramaco was mainly in response to the Wyoming Environmental Quality Council (EQC) comments who deemed the 7th application as inadequate for a number of issues. Rounds 9 to 12 submitted by Ramaco addressed further comments made by the Wyoming Department of Environmental Quality (DEQ). DEQ has determined the Round 12 mine application to be complete. Despite the Findings of Fact and Conclusions of Law by EQC, and having gone through 12 rounds of review with the Department of Environmental Quality, Ramaco only made a token effort to address the mine subsidence issues of the mine design. Because of the limited additional geotechnical information gathered by Ramaco, Ramaco's consultant Agapito Associates Inc. (AAI) of Colorado provides a Subsidence Control Plan (SCP) for only one seam and only the first area (TR-1) to be highwall mined, and even in this SCP analysis, there is a number of disclaimers/qualifiers to their findings. For example, AAI "DISCLAIMER:" … states … **"conclusions expressed herein are based on the facts currently available within the limits of existing data, scope of work, budget, and schedule.** Supporting data and information relied upon during the course of this investigation and used to prepare this report have been obtained from Ramaco Carbon records and files, available published reports and literature, personal communication with Ramaco Carbon staff, and other information sources. **Agapito Associates, Inc. makes no representation or warranty as to the accuracy of the data supplied and used in the development of this report"**(highlights added). This disclaimer is understandable given that only one additional hole was drilled and sampled with geotechnical testing for only one seam (the non-split Carney Seam). Yet, even with AAI's qualification for the design of only the TR-1 area (68 acres), Ramaco applies for in the application to allow highwall mining of a total of 1,960 acres with all, or the vast majority, of the land with proposed multi-seam mining.

It is acknowledged that Ramaco has hired a mining/geotechnical consultant, AAI, to address subsidence potential issues since the EQC's recent rejection of the Brook Mine application. AAI has provided responsive mine design analyses and associated subsidence potential analyses. These reported analyses, however, do not meet the necessary standard for review or provide sufficient assurances that significant subsidence will not occur from the highwall mining. Consequently, because there has been no substantive change in the Rounds 8 to 12 submittals, the main opinions provided in our report to you on January 23, 2017 have remained unchanged. The January 23, 2017 report is attached for your reference. See Attachment B.

A detailed review of the submitted AAI's report, the mining plan, the Subsidence Control Plan (SCP), and surface reclamation is given below.

PROPOSED MINING

The proposed highwall mining (HWM) methodology has been discussed in MEA, 2017. Since this report, the current application calls for the strip mining of the Monarch seam and no planned mining of the Monarch seam (MP1-2.2, MP.4.4, MP.4.4.1, and MP.4.6). In other words, only the Carney Coal is planned to be underground mined at this time. Another significant change from the Round 7 application is the abandonment of the most eastern highwall mining area, formerly TR-1 (see Figure 4.3, MEA, 2017). As pointed out by MEA during Round 7, HWM in this area was not well thought out. It contains significant mine spoil from previous Big Horn strip mining operations, and consequently, was not practical.

The new proposed HWM TR-1 area consists of only one block (in lieu Blocks 3 and 4 formerly TR-2, see MEA, 2017). The new mine plan is shown in Figure 2. Comparing Figure 4.3 (MEA, 2017) to Figure 2, it appears the changes in the mine plan only pertain to the old TR-1 and TR-2 areas. Consequently, the HWM areas which were Blocks 9 and 16 in Figure 4.3 still abut against old workings with minimum barrier coal of 0 to 70 ft. and consequently result in potentially flooding from the old workings to the south especially considering the likely inaccuracies of the mine map of the old works. Based on historical mapping, the floor depths in the minimum barrier areas are about 87 to 115 ft. in the new TR-4B, 5, and 7 areas. See Figure 2. Based on various empirical relationships on the minimum confirmed barrier thickness, this barrier should be at least about 55 to 110 ft. (Koehler and Tadolini, 1995), and therefore all areas (TR-4B, 5, and 7) would exceed the minimum confirmed barrier width depending on what criterion was used. Moreover, MSHA requires a minimum coal barrier width of 200 ft. for underground mining next to abandoned workings (30 CFR 75.388).

The general information on the room and pillar dimensions and panel, and coal barrier widths has remained unchanged. Only for new TR-1 area was more specific HWM design criteria proposed for the unsplit Carney Seam. For the maximum recommended extraction with a mined coal height of 14 ft. (Add. MP-6-42) and room width of 11.5 ft. (Add. MP-6-36) AAI determined the following (Add. MP-6-47).

Panel	Design Depth	Web Pillar Width	Panel Extraction	Tributary Pressure
1	266 ft.	14.1 ft.	45%	544 psi
2	279 ft.	14.2 ft.	45%	571 psi
3	333 ft.	17.9 ft.	39%	614 psi
4	338 ft.	18.3 ft.	39%	623 psi

AAI, however, assumed that only the Carney Seam will be mined in TR-1. For the TR-1 area, both the overlying Monarch and underlying Masters coal seams have mineable thicknesses (see Table 4.1, Block 4, MEA, 2017). Even though these seams are not currently planned to be underground mined, no comment was made by AAI on design of multiple seams. It should also be noted that no consideration is made in the design for the pillar loading imposed by the planned stockpiles of mine spoils depicted in the Exhibit MP.1-2. This exhibit shows the stockpiles to be as wide as about 500 ft. and as long as about 1,500 ft. These stockpiles could reach significant heights with no restriction.

GEOTECHNICAL DRILLING AND TESTING

The proposed geotechnical drilling and testing after Round 7 for the proposed future underground mining areas has generally become less stringent and more ambiguous as modifications were made to the permit application by Ramaco. In its final form, Ramaco states "in future highwall mining blocks outside the study (TR-1) area, additional hole(s) covering a similar area are appropriate, with a similar suite of tests" ... in the roof, coal and floor of the Carney Seam as has been performed in the TR-1 panel (Ramaco Responses to Round 8 DEQ Memorandum of Deficiencies dated January 14, 2019). Ramaco further stated in the permit application that "prior to initiation of auger mining activity, samples will be collected and strength testing will be conducted … in order to satisfy the requirements of the MSHA ground control plan which must be approved prior to mining." These test results and analysis "will be provided to WDEQ/LQD" prior to mining.

In Appendix D5 – Topography, Geology & Overburden Assessment dated 12/19 prepared by WWC Engineering, it states tensile strength results will be used to size web pillars and barrier pillars to achieve SF set by MSHA ground control plan to conduct mining and minimize the risk of subsidence.

Below are the issues related to the above proposed geotechnical drilling and testing in the mine application.

1. The one geotechnical boring which was done in the TR-1 area, which is 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 areas or, for the matter, all of TR-1 appears inappropriate.

2. The promised number of geotechnical test holes and testing on what strata per HWM area is vague and undefinable as given in the above statements and in the application. Therefore, these geotechnical promises are not enforceable.

3. Specific types of geomechanical testing are given but they will provide a deficient assessment of long-term strength and should include the consolidated drained triaxial tests which were originally promised after Round 7. Also, no Atterberg Limits are stipulated which really assist in rock classification, the potential for softening, and softened strength parameter values.

4. Use of the tensile strength for determining the pillar strength by Ramaco as noted above is not appropriate and should not be allowed.

5. The exploration and testing program proposed in the mine application assumes only the Carney seam will be mined without any geotechnical provisions if multi-seam mining were to occur in the future.

6. DEQ should regulate the number of holes and testing required, not the mining company. Undefinable information supplied by Ramaco where future data and analysis are promised at an undetermined time prior to mining and without noted approval of a SCP by DEQ. Moreover, the data and analyses promised are related to MSHA requirements which are not focused on surface subsidence above HWM areas.

MINE STABILITY ANALYSIS

Ramaco's Approach

In response to EQC's Finding of Facts and Conclusions of Law – Round 7, Ramaco cites "Brook plans to do the necessary engineering work Dr. Marino suggests as part of the ground control plan Transcript – Barron testimony, pp. 1532-1533 (Comment EQC 60 – Round 7)". This was not done. The main concern is the assessment of the long term stability of the mine design analysis to prevent mine subsidence. In an effort to ensure that the "necessary engineering work" was done, long term stability design guidelines were provided and for convenience are provided in Attachment C. Instead, Ramaco ignored significant portions of these guidelines. Ramaco hired and directed AAI to perform design analyses for mining of one seam in one area (TR-1), see Figure 3. AAI utilized in design only one test hole in the TR-1 area with insufficient testing. Using this provisional design, however, Ramaco applied for a permit to mine the whole proposed mining area. The area of HWM of one seam that AAI provisionally designed for was about 68 acres compared to a total of about 1,960 acres of HWM applied for. Since no engineering analysis was performed for the multi-seam HWM condition, the submitted mine plan was absent of any criteria on the allowable thickness of the interburden for the different lithologic and mining conditions.

Because AAI's design report is incomplete in many respects, a complete critical expert review was not possible. This includes:

- No codified rock classification for understanding material types.
- Point data not provided for Carney Coal Thickness with contours of 0.5 ft. (see AAI Figure 3).
- Point data not provided for Carney Coal floor elevations with contours to 1.0 ft. (see AAI Figure 4).
- AAI states: "Unmapped faults may exist that complicate the seam structure" (Add. MP-6-24), but are not addressed in the design.
- Joint (fracture) pattern assumed in UDEC modeling used to check for mine instability not given (Add. MP-6-55).
- Joint slippage properties assumed in UDEC modeling used to check for mine instability not given (Add. MP-6-56).
- No reference for the assumed "western coal" strength.

- No long term strength data for the mine roof or floor.
- No analysis provided on how the floor stability was determined to be adequate (Add. MP-6-38,39).

In the analysis below, the fine-grained rock overburden and floor in the test hole (Boring 2017-4) done for the design of the TR-1 HWM area are classified as mudstone and is assumed as such in AAI stability analysis. It is unreasonable, however, to assume a roof and floor containing mudstone as the worst case condition when there is a significant amount of roof and floor material described as claystone in the other borings submitted in the application, especially without running, at a minimum, Atterberg Limits to verify the rock plasticity. These fine-grained clastic rocks are very difficult to properly identify without this testing (Marino and Osouli, 2012).

Below is the review of limited AAI mine design analyses against mine roof, pillar and floor failure based on the information available in the AAI report. See Figure 3.

Roof Stability Design Analysis

For the TR-1 area, AAI analyzes the mine roof short term stability for highwall mining. Because of the reported weak mudstone beds, AAI recommended leaving 1 ft. of coal in place to avoid short term collapse of the more immediate roof rock, although the more immediate mudstone is likely to collapse in the long term. AAI calculated a roof stand up time of only 77 days (Add. MP-6-38). AAI noted, however, that above the 6 ft. of strata of essentially mudstone sequences is a “18+ ft.-thick sequence of moderately strong sandstone that may be sufficiently competent to bridge across the 11.5 ft. opening width.” In view of the reported overburden geology across application area as discussed in MEA, 2017, these sandstone beds are laterally discontinuous and thus, should not be relied upon as being omnipresent. Furthermore, evidence that sandstone is sufficiently present with adequate capacity in the overburden is not borne out by the massive amount of pit subsidence over the adjacent old works which are in the Carney Seam (see MEA, 2017).

Pillar Stability Design Analysis

For HWM in TR-1, AAI offers two designs: one with a stability factor (SF) of 1.6, and another where SF is 1.8 “to reduce the likelihood of pillar failure” (Add. MP-6-39). SF is calculated using the program ARMPS-HWM. This design methodology was developed for bituminous coal fields with web pillar heights of 7 ft. or less. The application conditions, however, fall outside this criteria. The Carney Seam is sub-bituminous coal and is 16-17 ft. thick in the TR-1 area reaching 18+ ft.-thick across the application area (see Table 4.1, MEA, 2017).

As stated by AAI, “Mark and Barton (1997) concluded that laboratory test results (typically from tests on 2-3 in. core) are a poor predictor of in-situ pillar performance, and that a constant in-situ coal strength of 900 psi (when considering 36” or greater cubes of inplace coal) produce better results” (Add. MP-6-40). However, AAI correctly recognized, as noted in MEA, 2017, that bituminous coal would have a higher strength than the Carney sub-bituminous coal. Therefore, AAI assumed in-situ coal strength of 762 psi. Rationale to arrive at 762 psi, however, defies logic. AAI justified the reduction from 900 psi to 762 psi for sub-bituminous coal based on the reduction of an unsubstantiated laboratory compressive strength for “western coal” to that for the Carney Seam (from Test Hole 2017-4). Yet by their own admission, lab tests do not relate to the larger in-situ cube strength. In addition, it is not known if the “western coal” strength was from bituminous or sub-bituminous coal or how it was derived. Moreover, AAI then claims the derived strength of 762 psi is “more conservative” without explanation (Add. MP-6-40).

Roof/Floor Bearing Design Analysis

AAI describes the immediate 6 ft. of the Carney roof as weak carbonaceous mudstone to mudstone which becomes sandy towards the top (Add. MP-6-33, 75-77). The carbonaceous mudstone was found to be non-durable with Slake Durability Index (SDI) of only 11.8% (Add. MP-6-32). As noted above, AAI calculated this roof’s “stand up time” to be 77 days. Because of the concern for fallout during mining, however, AAI recommended leaving 1 ft. of sub-bituminous coal in the roof. However, whether or not this coal thickness can be remotely controlled or maintained if the coal thins or undulates, and how long the coal (without bolting with mesh) will remain are suspect. Caving in the long or short term of the weak immediate roof adversely affects the roof’s ability to laterally restrain these mudstone strata above the pillar from roof squeeze. Based on the pillar design at SF=1.6, web pillar width to weak roof thickness ratio ($\frac{W_p}{h}$) would range from 2.35 to 3.0 for Test Hole 2017-4, and would be clearly susceptible to roof squeeze. No roof bearing analysis was performed by AAI.

The upper almost 2 ft. of the floor is described as carbonaceous mudstone which AAI states “is not expected to provide adequate floor conditions in a wet environment.” This non-durable immediate floor had a reported SDI of only 22.4% with a very high natural moisture content of 18%. This material is underlain with at least 14 ft. of mudstone which is described as “weak, plastic mudstone which would form a very poor floor.” This rock tested to be fairly non-durable with SDI’s of 59.7% and 71% and with a high natural moisture content of 12.8%

(Add. MP-6-32-33)[1]. At the termination of the test hole, these mudstone sequence was at least about 14 ft. thick.

AAI also recommended leaving 1 ft. of sub-bituminous coal cover as a result of their concern for the floor conditions. This may assist in the immediate short term with HWM trafficability, if it can be done, but provides little benefit over time to restrain floor heaving. Given these floor conditions, $\frac{W_p}{h}$ is no greater than 1.3 for Test Hole 2017-4 and thus clearly more susceptible to pillar punching.

As noted above, AAI recommended the use of 1 ft. of roof and floor coal in their report. However, they later stated in response to a DEQ Deficiency Letter (Ramaco response to DEQ Memorandum dated December 27, 2018 by R. Barney) that the need for this roof and floor coal was not expected to be the normal condition. Consequently, an extraction height of 16 ft. should be considered in lieu of 14 ft. in the TR-1 area. Therefore, AAI analyses which assume an extraction height of 14 ft. are not most representative of what is expected in the TR-1 area.

AAI only performed a bearing capacity analysis on the mine floor. AAI stated “the bearing capacity stability factor of the CMS (carbonaceous mudstone) floor layer was calculated to be greater than 2” (Add. MP-6-39). AAI appears to erroneously ignore any failure through the underlying “weak, plastic mudstone.” Moreover, no details of this important analysis are provided for review. However, it is stated that the bearing capacity analysis was done considering the cohesion and internal friction angle values for each layer as given in AAI Table 8. For the floor materials, AAI assumed cohesion and friction values of 243-553 psi and 20.9-29.2° respectively.

From our experience with mudstone floors, the strength values assumed by AAI for the fully softened and unsoftened conditions are too great (Marino and Osouli, 2012). AAI described these mudstones being weak and plastic yet while the friction angle values are reasonable, these assumed cohesion values, which are the dominant factor in determining the AAI calculated bearing capacity are too high. In fact, from a significant amount of testing we have done, the cohesion can drop to essentially zero in the fully softened state leaving only friction to resist bearing failure[2]. In the softened state, the bearing capacity of the non-durable mine floor with initial moisture contents of about 13% (as reported by AAI) can be easily below the design pillar pressures of 544 psi to 623 psi noted above. Moreover, it is unknown how these strength parameter values were specifically extrapolated by AAI since

[1] From our experience, given a reported material moisture content of about 13% these reported SDI appear high.

[2] Although the extraction ratio proposed by AAI is below 50%, significant softening is expected below the web pillars because they only reach widths of about 18 ft. and $\frac{W_p}{h}$ is no greater than 1.3

they were not directly measured from any reported laboratory tests performed yet very specific. And, it is unknown why AAI only considered shearing in the top 1.8 ft. of carbonaceous mudstone (Add. MP-6-39) and ignored deeper seated failure into the "weak, plastic mudstone," which is likely the more critical condition.

In fact, the UDEC modeling used to "check roof and floor for stability, and detect other potential failure mechanisms" considered the mudstone floor to also have a tensile strength ranging from 76 to 89 psi per layer in addition to the unrealistic cohesion, thereby further increasing the floor strength and improving stability. Note, in the unreported bearing capacity analysis, AAI stated no tensile strength was assumed. Use of a tensile strength in unsoftened to softened mudstone floor is completely unrealistic and reduces any indicated instability results.

As can be seen from the above, AAI using unreported bearing capacity methodology, arrived at acceptable floor stability using unrealistic floor strengths even in the unsoftened state. AAI did not consider the much weaker moisture softened condition despite moisture deterioration potential indicated by their only durability tests.

This floor will most likely be exposed to groundwater as a result of a number of factors:

- Even if a 1 ft. coal cover is considered, groundwater will seep through exacerbated by cracking in the coal from any significant floor heave from pillar punching and swell of floor materials from exposure to moisture.

- Groundwater exposure from unmapped faulting or shear zones, roof collapse uncovering beds seeping groundwater, surface runoff through complete chimney collapse events and the HWM opening, and flooding from adjacent old works.

AAI reported "It is expected that aquifers are associated with the coal seam(s) and adjacent sandstones with intervening shales and clays inhibiting vertical movement. Some groundwater inflows can be expected during highwall mining operations" (Add. MP-6-24,25).

AAI also investigated the potential for "cascading pillar failure," or in other words, the potential of an outward progressive failure from localized pillar crushing or compression. This was analyzed using a program called LA Model. This software calculates the transfer of stress to adjacent previously unyielded pillars through bridging (or arching) in the roof overburden. However, the LA Model does not account for roof/floor bearing deformations and therefore this analysis is not valid given the site conditions. Moreover, given the reported mudstone roof and floor, it is not reasonable to consider there is not significant yielding of roof/floor which affects the outward progression of pillar failure especially since the failure is most likely in bearing not in the pillar.

SUBSIDENCE ANALYSIS

Surface subsidence is an expression of an underlying mine collapse. Over room-and-pillar workings subsidence develops in the form of sinkholes (aka pits) and bowl-shaped depressions (aka sags over room-and-pillar mines). Pits and smaller sags are caused by chimney roof failure above a mine opening, whereas larger sags result from yielding of a number of pillars from outright crushing, or roof/floor deformation (see UPDATE 14).

Pit Subsidence

The potential for pit or chimney subsidence was evaluated by AAI for only the TR-1 area for highwall mining of only the Carney seam. AAI concluded "the risk of sinkhole subsidence associated with highwall mining at the Brook Mine is considered low, but cannot be dismissed entirely, particularly in the shallower cover areas near the box cut (or highwall)." This opinion was in part based on a study of pit development in Colorado performed by Matheson, 1990, who developed the following equation to estimate the probability of pit subsidence.

$$P=1{,}516\left(\frac{D}{H}\right)^{-4.0}\quad\left(\text{for } \frac{D}{H} \geq 6.3\right)$$

where: D = depth of floor of opening
H = mining height
P = probability of pit subsidence

This probability model by Matheson was not applied by AAI as the data relied upon for this model excluded the case data AAI used in their analysis for sinkhole development potential above the proposed Brook Mine. Consequently, the above equation is not applicable. AAI used Matheson's excluded Colorado case because it better represented the room-and-pillar conditions proposed at the Brook Mine. From the excluded case data of 82 observed sinkholes, AAI determined the 100% probability was when $\frac{D}{H}$ equaled 2.7. Also, the Matheson probability is somewhat a misnomer as it actually is based on the frequency of subsidence occurrences per unit area.

With the use of the Matheson case data, AAI determined the frequency of observable sinkholes per unit area for different mine depth ranges. AAI added similar results were obtained when examining the observable subsidence over the adjacent Carney, KOOL and Monarch mines to the Brook Mine. With the use of these depth related frequencies, AAI determined that 7 sinkholes may develop using the Matheson Model to a depth of 178 ft. and none should develop beyond this depth. This, however, is only for the TR-1 area where the extraction height was erroneously assumed at 14 ft. AAI also noted 7 sinkholes was considered a conservative estimate since the HWM entry width of 11.5 ft. of roof span, was less compared to the Matheson studied mined-out area.

In performing a "probability" analysis of estimated number of sinkholes in the TR-1 area, AAI adopts the Matheson $\frac{D}{H}$ model. However, in the Matheson reference used by AAI, the definition for D is mis-stated and thus, inappropriately applied by AAI in their sinkhole analyses. D is the depth to the coal seam or the overburden thickness as indicated to Figure 4 and Table 3 of Matheson, 1990[3]. Also, this definition of D does not intuitively make sense and is not traditionally defined that way. Moreover, given that the "normal condition" for TR-1 is <u>not</u> to leave coal in the roof and floor, H will be 16 ft. not 14 ft. as assumed. Therefore, Table 9 in the AAI report was redone using the appropriate values and is provided in Table 1. This is analysis results in a predicted 16 sinkhole (distinct subsidence) features compared to 7 estimated by AAI. For the remaining HWM application area, these calculations with assumptions by HWM panel are given in Tables 2 to 15. Using this chimney subsidence prediction methodology by AAI, 2,680 sinkholes (1.4 subsidence events/acre) are estimated over the entire proposed HWM area. With this number of events, it is clearly not an unplanned subsidence plan.

Even though the AAI chimney subsidence prediction method appears inappropriate and an excessive over-estimate on the frequency of events, it does not provide any confidence that future chimney subsidence is not problematic. Moreover, the risk of surface subsidence from HWM entry roof collapse should also account for the following factors.

1. The less distinctive chimney features or sags will not be noticeable from the aerial photography used in the AAI analysis count subsidence events. In other words, the subsidence count made by AAI would be only for the more dramatic features which can be seen from high elevation aerial images. It would not include all the smaller pits or smaller to larger sags or troughs. Therefore, the prediction of "probability" of chimney subsidence (pits and smaller sags) underestimates the frequency of subsidence events.

2. In the current application, the Monarch seam is no longer highwall mined. It is only planned to be surface mined throughout the application area (Figure MP-6.1-1). Based on Figures 4.3, 4.1, to 4.24 in the 2017 MEA Report. The Monarch seam is shown present in Mine Blocks 13, 17, and 20. Surface mining in these areas will remove at least up to 35 to 105 ft. of overburden, the vast majority of which is rock and will be replaced with mine spoil. The reduction of the rock overburden in these

[3] D is mis-defined in the text of the paper. Note, if D were taken as floor depth, the overburden thickness to mined height would not be 2.7 at < 25 ft. depth.

areas with clayey mine spoil will clearly increase the risk of surface subsidence from HWM entry collapse from the underground mined Carney.

3. AAI chimney subsidence analysis does not account for the "portal" subsidence at the tapered back highwall. Also, data on how closure of the HWM openings will be addressed is not provided, for example, will the mine spoil be merely dumped in front of these HWM openings, as implied.

4. The method of "probability" used by AAI given above for sinkhole subsidence for HWM of the Carney seam in the TR-1 area is also in conflict with the methodology provided by Ramaco in the Subsidence Control Plan (SCP) for the overall application area. This methodology is discussed in detail in MEA, 2017. The methodology used by Ramaco recognizes the importance of other parameters in prediction of chimney subsidence which is ignored by the "probability" criteria used by AAI. Chimney prediction methodology (e.g., Piggott and Eynon, 1977, Garrad and Taylor, 1988, Whittaker and Reddish, 1989, and Dyne, 1998) typically considers at a minimum the bulking (volume expansion) from the caving of intact roof rock, the extraction height, width of intersecting mine openings and the repose angle or the spread of the caved material into mine openings. This was exemplified by Ramaco in Figure MP-6.2-4 (see Figure 4).

Sag Subsidence

AAI states that "the highwall mining plan (for the Carney seam in the TR-1 area) for the Brook Mine has been developed to minimize the likelihood of trough (sag) subsidence"… (Add. MP-6-62). As noted above, sag subsidence from pillar bearing failures into the "weak" "plastic" mudstone floor (and possibly roof) appears likely. This type of failure would cause sag or trough subsidence in addition to smaller sags from chimney subsidence. From a study performed by the USGS in the project area, Dunrud and Osterwald 1980 illustrated both trough and pit subsidence from the area, which is shown in Figure 5. Note, the USGS illustration depicts pit/sinkhole subsidence inside a larger sag. This indicates at shallower depths where sinkholes occur, massive pillar related failure would also occur. In addition to outright crushing, pillar failure can be induced by excessive deformation in the weak adjacent mudstone. Moreover, AAI notes that pillar failure can cause spontaneous combustion (Add. MP-6-21). Coal fires are not uncommon in the area and can result in additional subsidence and possibly other environmental concerns. Moreover, in review of the mine application, the Wyoming Land Quality Division (LQD) noted in a Memorandum dated December 27, 2018 that "leaving coal in the roof and the floor (as proposed by AAI above) there may be increased chance for spontaneous combustion of coal and coal fires. Coal fires could potentially weaken pillars."

SUBSIDENCE REMEDIATION

In the mine application, Ramaco discussed their remediation plan if chimney (sinkhole) subsidence would result over the proposed HWM area. Ramaco stated that areas highwall mined will be “monitored for at least 6 months after highwall mining of the individual areas are completed. If there is no evidence of subsidence, then the monitoring of the area will be discontinued” … “Backfill” of the detected subsidence will however only be “performed on a selective/as-needed basis.” The select subsidences which will be remediated will be only those which do not exhibit “self-healing” and there is the introduction of oxygen or surface water. Ramaco notes it “will continue to perform remediation on any subsidence, detected during or subsequent to the 6 month monitoring period, until bond release is approved” (MP-6.3 and MP-6.4).

The above remediation plan does not require any monitoring above HWM areas beyond 6 months, and only remediates those which are not “self-healing” in lieu of remediating all sinkholes. Moreover, “self-healing” is not sufficiently defined. If the sinkhole collects water, would that mean it has “self-healed”? In lieu immediately “backfilling” the pit, is there a waiting period to determine if it will “self-heal”? It is also unclear how the pit will be backfilled.

From our experience, at a minimum, backfilling a subsidence event in an open field should include compaction of the subsidence bottom and then compaction of the subsequent lifts of select fill placed in depression. The backfilling should continue to at least meet the natural surrounding surface contour, and as noted in the application, be covered with topsoil that supports the vegetation demand. Although not even considered in the Ramaco SCP, remediation should also apply to trough or sags which have significant depth affecting surface drainage.

It should be noted that the Ramaco subsidence remediation plan falls way short of the reclamation efforts performed by the State on the subsidence features which have resulted above the adjacent abandoned Carney Mine No. 44 (PHC Reclamation, 2006).

Criteria is recommended by AAI for “any surface structures or other facilities” that would require protection from subsidence for HWM. Their report states “AAI considers a 50 ft. offset and an angle of critical deformation of 25° to be appropriate.” Under the most likely site conditions, this criteria appears to be acceptable.

SURFACE RECLAMATION

In Section RP.3.3 entitled Post Mine Slope Analysis, the reclaimed land slopes are reported from 0 to greater than 45° and are in fact, noted to 69.5° (Table RP.3-1) without distinction of which slopes are native or reclaimed. It is not known whether the greater slopes are in native rock or highwall areas, or native or reclaimed soil slopes. Further, there is no discussion of how the reclaimed slope will be constructed to prevent landsliding conditions, or analysis of the stability of such slopes. Given that the majority of the mine spoil will likely consist of rubblized claystone, only gentle slopes should be tolerated.

DEQ OVERSIGHT

In Round 7, DEQ admitted it has only limited expertise in mine subsidence engineering. This explained the blatantly inadequate review of the subsidence engineering aspects of the Brook Mine Application. In lieu of soliciting an expert in mine subsidence, the agency had in effect acted as a "pass through" in determining that the application was technically complete in this respect.

Recognizing that they did not have sufficient expertise to evaluate the subsidence engineering aspects of the Brook Mine application, after Round 7 DEQ contracted with Engineering Analytics, Inc. (EAI). Engineering Analytics scope of work was "to provide an evaluation of a subsidence sampling and analysis plan" of the Brook Mine Submittals and to provide "evaluation of the adequacy of Brook Mine's submittal in addressing each subsidence finding in the EQC order" (EAI Technical Memorandum dated June 19, 2018 and DEQ Memorandum dated October 16, 2018).

Accordingly, Mr. Dan Overton of Engineering Analytics notes in a Technical Memorandum dated June 29, 2018 that the EQC recommended "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)". These suggestions and concerns were spelled out in the 2017 MEA Report (see Attachment B) and the document entitled: Room and Pillar Recommendations Against Surface Subsidence – Proposed Brook Mine, Sheridan, Wyoming (see Attachment C) and in an initial review of items from the Round 8 application provided to DEQ in an email dated December 31, 2018. The MEA report and recommendations documents were in the possession of the DEQ in addition to the EQC prior to their written order. Based on the review of the most recent Brook Mine application documents, which was deemed complete, our concerns provided in these above documents were substantially ignored. Furthermore, there is no evidence, other than possibly MEA 2017, that these documents were even received or considered by Engineering Analytics, despite EQC findings. Note, there is no reference to any of these documents in any of EAI's reports.

From review of their Technical Memorandums on the Brook Mine submittals related subsidence issues, Engineering Analytics performed no independent critical analyses of the mine design and associated subsidence potential as performed herein. The vast majority of the EAI Technical Memorandums are a regurgitation and explanation of Ramaco's submittals. However, EAI properly identified the use of consolidated drained triaxial tests in one of the earlier reviews (Technical Memorandum dated June 29, 2018). In this earlier memorandum, EAI states the Brook Mine "subsidence sampling plan is not sufficient as presented" and their plan "remains deficient" in all subsidence related phases. Given the subsequent responses by Ramaco, it is unclear how these major issues were resolved.

Moreover, DEQ provides no geotechnical guidelines or requirements for mine subsidence engineering, such as: minimum required drilling and testing requirements, design methodology, minimum safety or stability factor criteria, protection requirements against subsidence for surface infrastructure, and minimum subsidence remediation requirements. In fact, without such constraints, DEQ had accepted Ramaco explanation that the mine design "will be done in due time."

In terms of subsidence remediation and surface reclamation, DEQ accepted vague and minimal subsidence remediation and reclamation standards. These subsidence standards are far below even the State's own standards as evident by the subsidence reclamation efforts by the State conducted above the adjacent abandoned Mine No. 44.

SUMMARY AND CONCLUSIONS

The findings from this investigation are provided below.

1. Ramaco Resources, Inc. has submitted several rounds of application for the Brook Mine (Rounds 8 to 12). Despite the Wyoming Environmental Quality Council (EQC) comments regarding the technical deficiencies in the applications associated with the subsidence issues of the application from Round 7, Ramaco responded with merely a token effort to address EQC's concerns.

2. Through their consultant, Agapito Associates, Inc. (AAI), Ramaco provided in their Round 8 application more specific mine design criteria for a highwall mining (HWM) of about 68 acres for one coal seam while applying for a total of 1,960 acres of HWM mining. Even their consultant, AAI would not extend their provisional design (with disclaimer) beyond the 68 acre area and just for the unsplit Carney seam with only one new test hole done in supposedly the 68 acre area.

3. Because of lack of specificity, it is unclear how extensive the geotechnical exploration and testing will be, but it clearly lacks long-term stability assessment investigation.

Also unidentifiable, are the types of future mine subsidence engineering analyses that will be performed, and when they will be submitted to DEQ for future HWM areas.

4. In the design analysis, AAI treats the anomalous conditions in one test hole to be uniformly applicable across the entire 68 acre HWM design area. These anomalous conditions depicted in the one test hole and relied upon, may be the cause for AAI disclaimer on their recommendations. In this test hole, the most critical roof/floor conditions are described as mudstone compared to all the other drilled holes in the application which report the presence of claystone – which is considered a more unstable material.

5. Ramaco and AAI do not adequately address the long-term instability of the proposed mine workings that could lead to subsidence. Ramaco and AAI do not account for the significant deterioration of at least mudstone roof and floor materials when exposed to moisture despite their own testing indicating such. In places, the design analysis lacked specificity and thus cannot be critically reviewed. For example, a more critical element of mine instability, which could lead to surface subsidence, are roof/floor bearing failures. AAI only reported a safety factor against failure of only the immediate mudstone floor without any calculations. Further, there was no analysis by AAI of roof bearing failure in the weak mudstone.

6. AAI determines for the TR-1 area that 7 distinctive subsidence features (aka sinkholes) may occur of this HWM area. After correction of this calculation this amount is more than double and over 2,000 such events are expected over the entire proposed HWM area using this methodology.

7. The proposed subsidence remediation by Ramaco in the application is ambiguous and allows for the possibility of many resulting subsidence events to remain untreated. This proposed subsidence remediation plan falls way short of the State's own reclamation standards. Moreover, the surface reclamation plan contains no slope stability analysis despite the steep proposed slopes.

8. With insufficient expertise in mine subsidence engineering, the Department of Environmental Quality (DEQ) has acted as a "pass through" agency through Round 12 and has contracted with Engineering Analytics Inc. (EAI) to review these aspects of the mine application after Round 7.

9. Based on the review of correspondence, DEQ did not provide their subsidence consultant EAI, MEA's suggested guidelines for room-and-pillar design against

subsidence for review (see Attachment B) and other MEA material to the application. The consultant subsidence did not include any significant critical analyses of the submitted application materials.

10. As noted above, the permit application only addresses the highwall mining of the 68 acres of Carney Seam. With application approval, this may provide an administrative mechanism for DEQ to approve remaining underground mining of other mineable seam areas without proper public oversight via a non-significant revision to the permit. This would involve the entire 1,960 acres of proposed highwall mining.

    At a minimum, it is recommended that any highwall mining be removed from the permit until it is reasonably investigated in order not to setup such a precedent of unacceptable protocols. HWM areas should be applied for increments as Significant Revisions as proper subsidence engineering investigation is accomplished. Moreover, in the first 5 years on operation the Brook Mine intends on only surface mining with no highwall mining. This is also consistent with Ramaco's statement in the application that the permit will be renewed every 5 years (Mine Plan prepared by WWC Engineering dated 12/19). Another reason why the HWM application should be delayed and become a Significant Revision is the statement by Ramaco … "AAI agrees that reevaluation should be considered if the ultimate plan involves a greater cutting width, height, or penetration or a lesser production rate than assumed" (Ramaco Response to Round 8 DEQ Memo of Deficiencies dated January 9, 2018).

QUALIFICATIONS

MEA is a leading expert in subsidence engineering from underground mining and from karst. For over 40 years, MEA's staff have provided services across the full scope of subsidence engineering, including significant work in research, site subsidence studies, mine stability design, failure analyses, prediction of subsidence displacement and damage potential, subsidence damage evaluation, foundation design, repair design, and grout stabilization design and monitoring. Being foremost in this field, MEA staff has authored over 100 publications on related topics and have worked in ore fields and karst across the U.S. and Canada. MEA's experience extends to underground mines in limestone, gold, trona, salt, lead/zinc, iron, and coal. Because of our broad reach, MEA is licensed to practice in 27 states.

MEA has also been hired by mining companies and others to provide consulting services on active or new operations for both room-and-pillar and longwall mining in addition to low to high extraction old works. These services are included in those listed above.

Because of the amount of coal mining related work MEA has done, it has designed and developed a cross-hole radar to detect mine voids for cases where mining may exist. Also, from our experience in karst, MEA has researched and developed a TDR system which can be used to detect incipient subsidence beneath a structure.

Having extensively worked on old workings and both low and high extraction active mines, MEA is uniquely qualified and separates itself from other geotechnical and mining engineering companies across the U.S.

If you have any questions about our review of the most recent Brook Mine Application, please contact us.

Sincerely,

Gennaro G. Marino, Ph.D., P.E., D.GE
President

ENCLOSURES:

REFERENCES

FIGURE 1	NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING COAL REMOVAL SEQUENCE
FIGURE 2	NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING THE ADJACENT OLD WORKS
FIGURE 3	SKETCHES OF THE THREE PRINCIPAL MODES OF FAILURE OF ROOM-AND-PILLAR MINE WORKINGS WHICH CAN RESULT IN SURFACE SUBSIDENCE
FIGURE 4	RAMACO ILLUSTRATION SHOWING THE VARIABLES INVOLVED IN DETERMINING CHIMNEY SUBSIDENCE
FIGURE 5	USGS ILLUSTRATION OF PIT AND SAG (TROUGH) SUBSIDENCE IN THE PROJECT AREA (DUNRUD AND OSTERWALD, 1980)
TABLE 1	REVISED AAI TABLE 9 SUBSIDENCE DATA FROM DEVELOPMENT – ONLY MINES – FOR TR1

REFERENCES

Dunrud, C. Richard., and Frank W. Osterwald, 1980. Effects of Coal Mine Subsidence in the Sheridan, Wyoming Area. Washington: U.S. Govt. Print. Off.

Marino, G. G. and Osouli, A., 2012. The Influence of Softening on the Mine Floor Bearing Capacity: A Case History. Journal of Geotechnical and Geoenvironmental Engineering.

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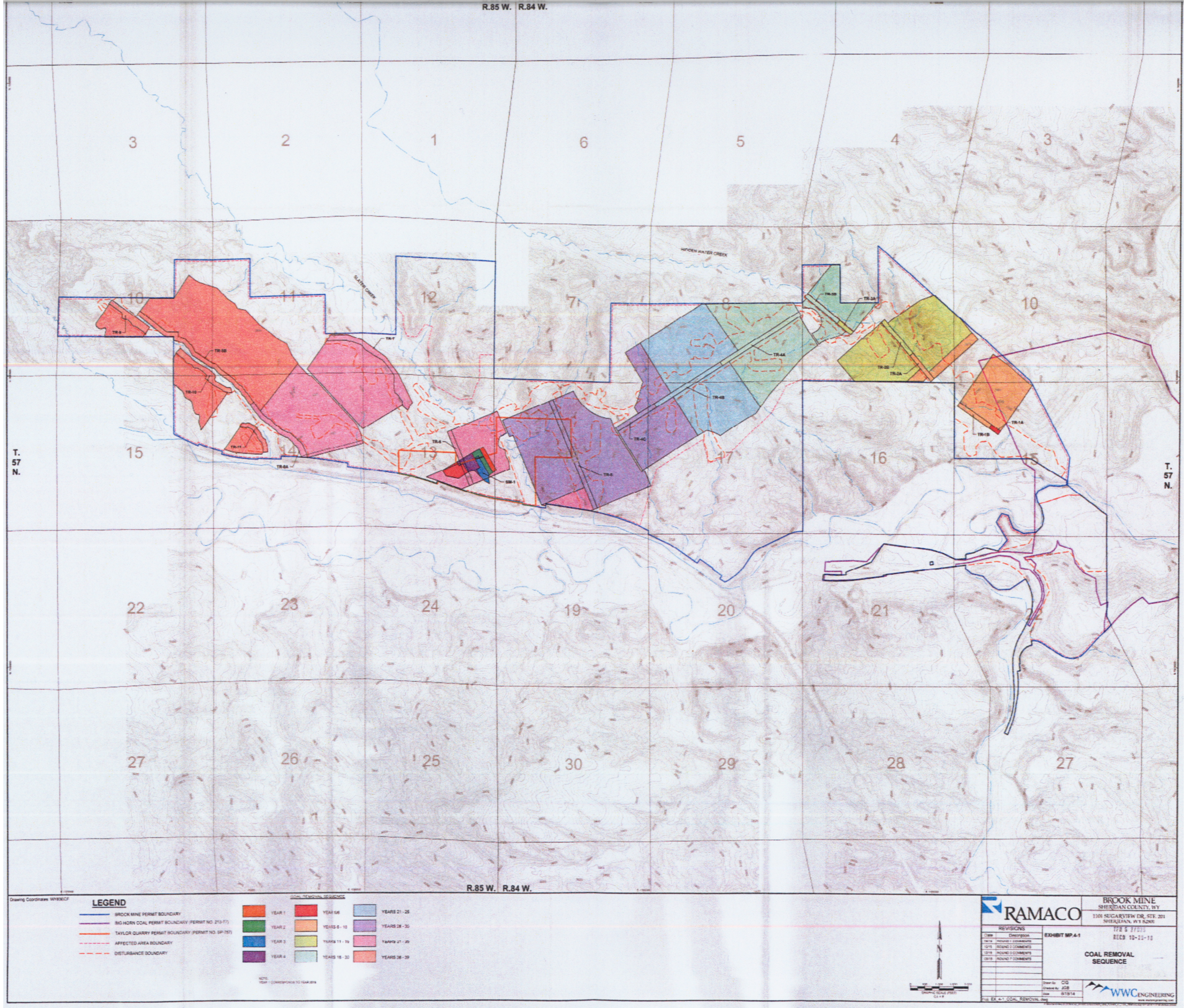


FIGURE 1   NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING COAL REMOVAL SEQUENCE

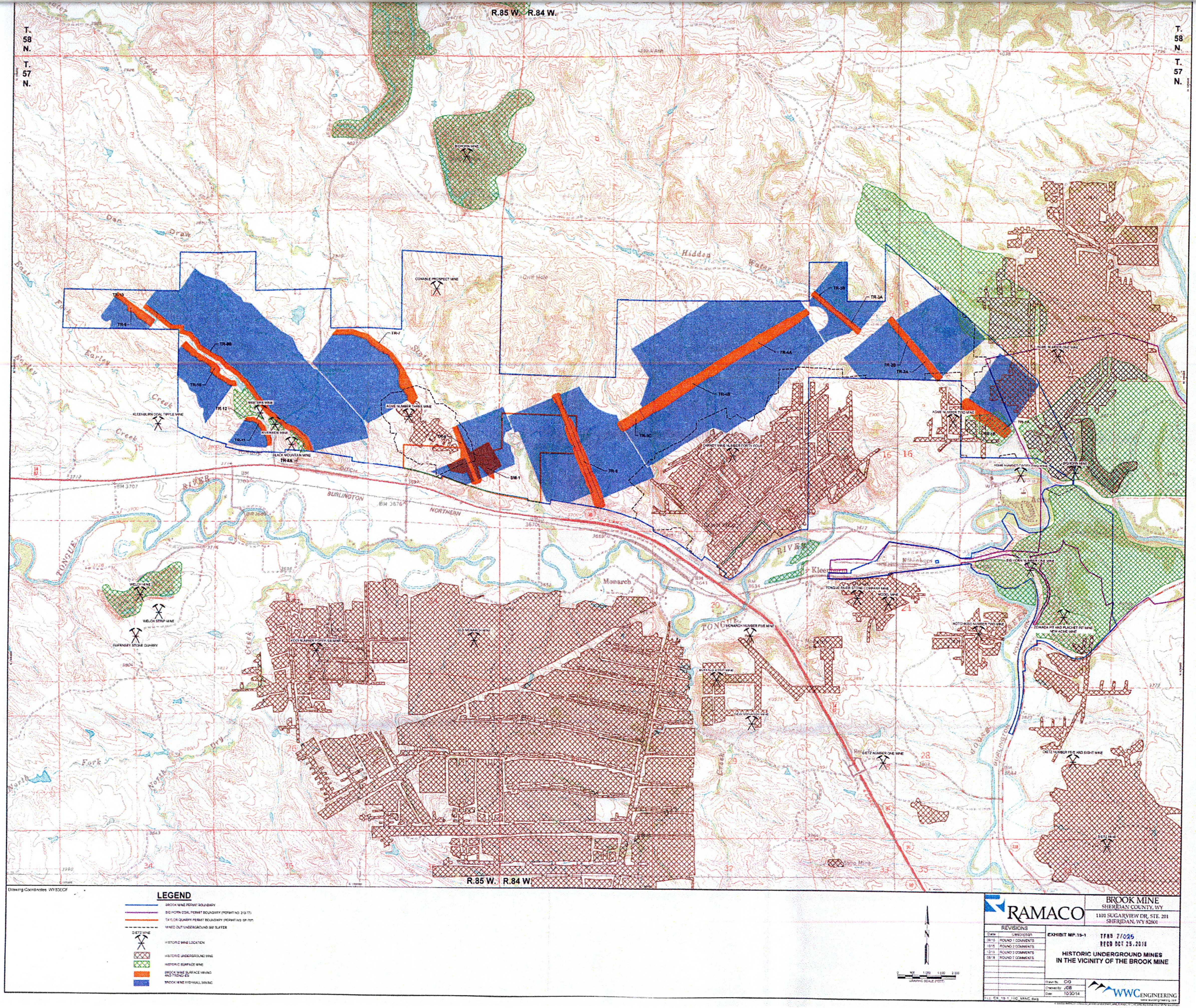
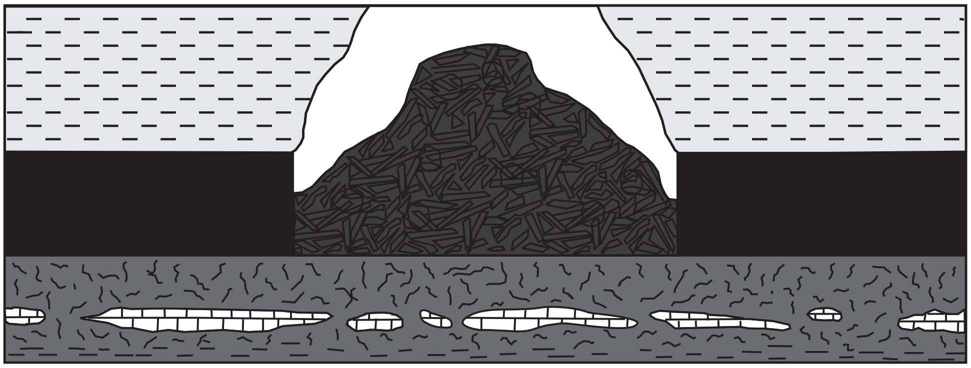
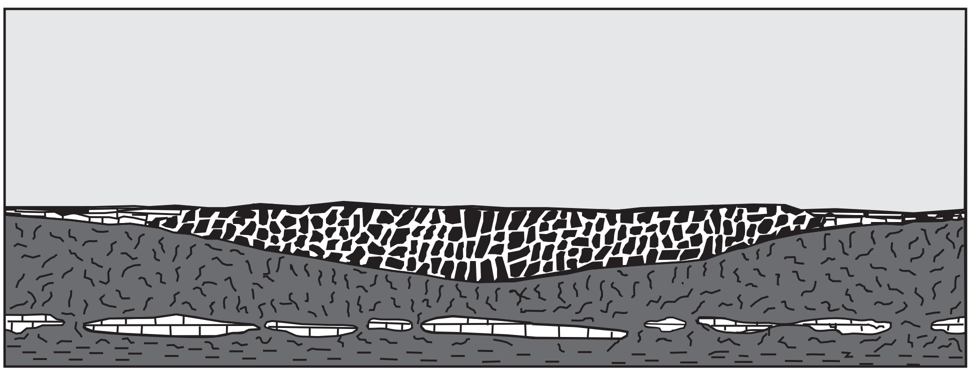


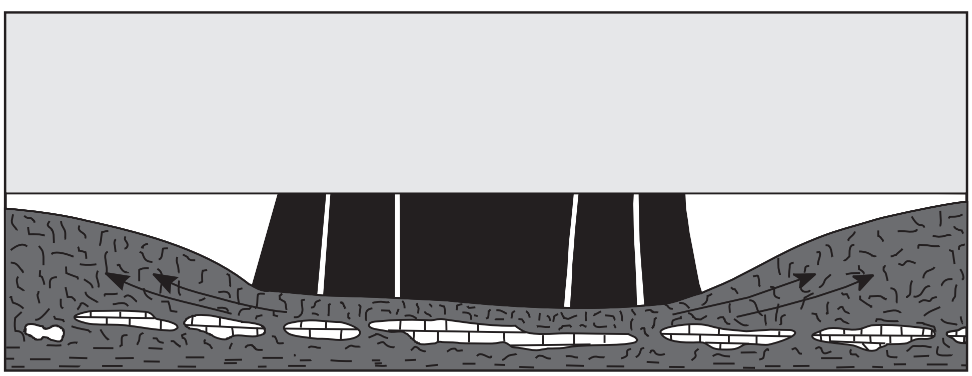
FIGURE 2 NEW PROPOSED MINE PLAN OF THE BROOK MINE SHOWING THE ADJACENT OLD WORKS



ROOF FAILURE ABOVE ROOM



PILLAR CRUSHING



PILLAR PUNCHING

FIGURE 3 SKETCHES OF THE THREE PRINCIPAL MODES OF FAILURE OF ROOM-AND-PILLAR MINE WORKINGS WHICH CAN RESULT IN SURFACE SUBSIDENCE

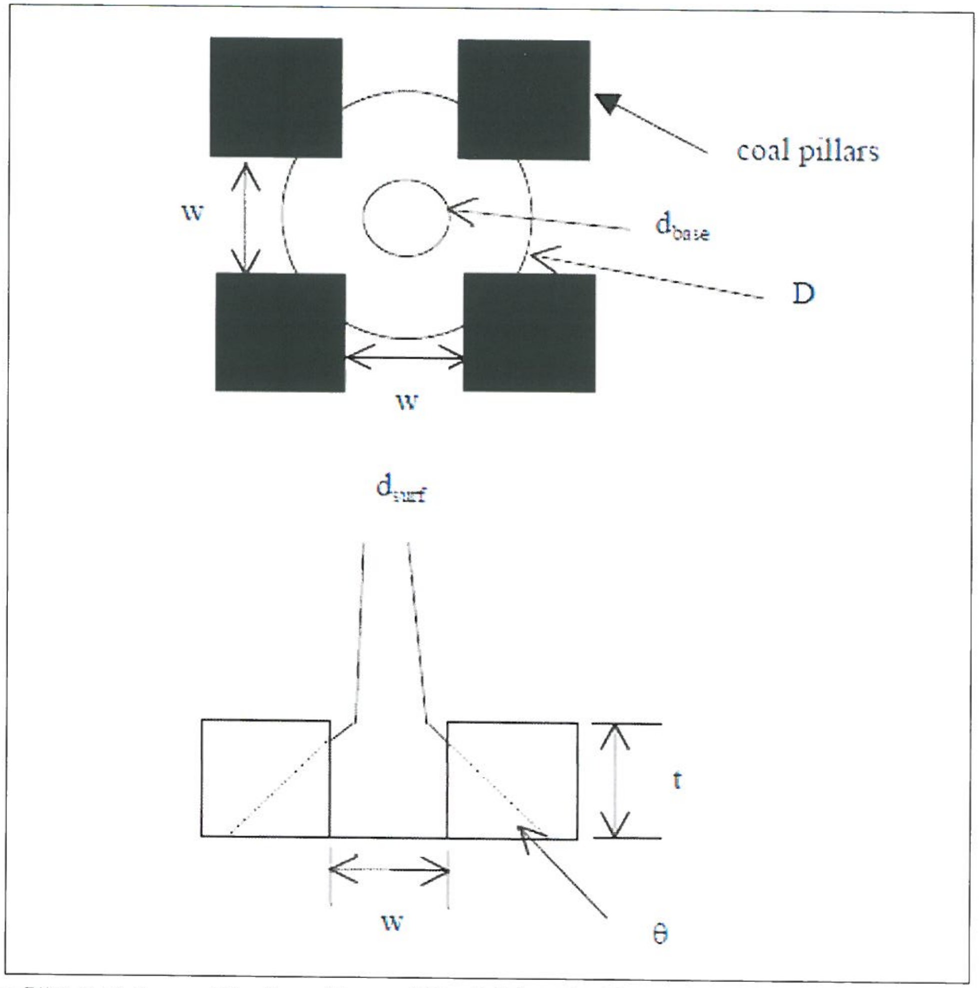


Figure MP-6.2-4 **Explanation of Variables in Equation MP-6.2-1 (Dyne, 1998)**

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FIGURE 4 RAMACO ILLUSTRATION SHOWING THE VARIABLES INVOLVED IN DETERMINING CHIMNEY SUBSIDENCE

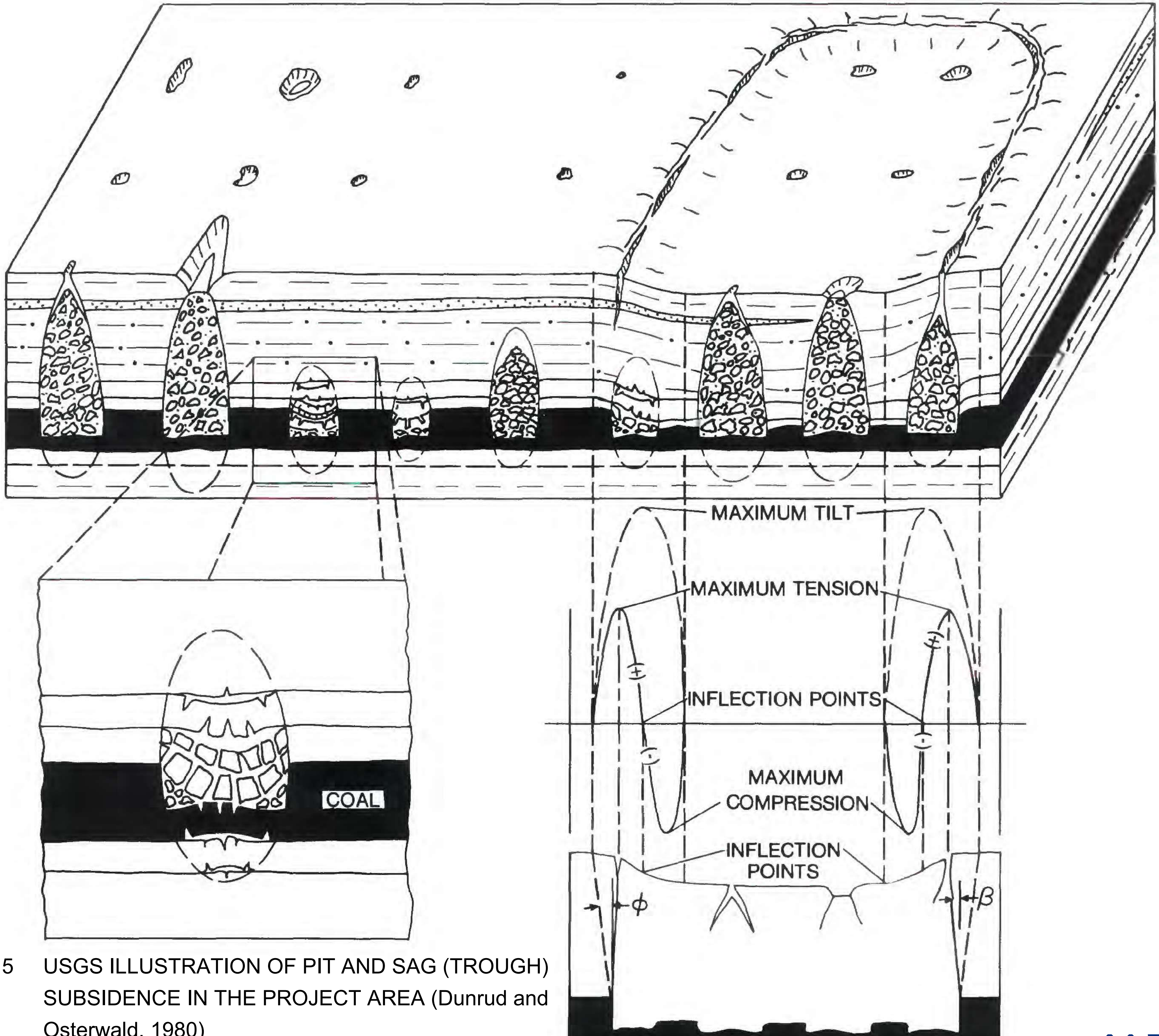

FIGURE 5 USGS ILLUSTRATION OF PIT AND SAG (TROUGH) SUBSIDENCE IN THE PROJECT AREA (Dunrud and Osterwald, 1980)

TABLE 1 REVISED AAI TABLE 9 SUBSIDENCE DATA FROM DEVELOPMENT- ONLY MINES- FOR TR1

Matheson Depth Range (ft)	Brook Mine Depth Range (ft)	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<25	<44	2.7	0.0	17.01	0.0
25-50	44-87	4.1	0.0	8.05	0.0
50-75	87-131	6.9	1.6	5.47	8.7
75-100	131-175	9.6	19.1	0.24	4.6
100-125	175-218	12.4	7.8	0.26	2.0
125-150	218-262	14.6	7.0	0.06	0.4
150-175	262-306	17.9	21.0	0.00	0.0
				Total	16

Notes:
1) TR-1 encompasses Panel 4 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 16ft.

TABLE 2 CARNEY SEAM TOTAL ACREAGE PER DEPTH INTERVAL, AVERAGE THICKNESS AND MINIMUM THICKNESS

							Thicknesses				
Trench	Panel	Total Acreage of Panel	0-115ft Deep (Total Acreage)	115-154ft. Deep (Total Acreage)	154-178ft. Deep (Total Acreage)	Shallowest Carney is Present. (FT.)	Average Carney (FT)	Average Upper Carney(FT.)	Average Lower Carney (FT.)	Interburden between Upper and Lower Thickness (ft.)	Add to Overburden Contours
TR-1	4	72	0.8	15.1	4.6	110	16.5	NA	NA	NA	NA
TR-2	5	78	12.8	3.3	1	55	16.5	NA	NA	NA	NA
TR-2	6	103	15.75	10	11.65	50	18	NA	NA	NA	NA
TR-3	7	16	16	NA	NA	30	11.5	NA	NA	NA	NA
TR-3	8	43	25.2	7	4.4	15	15	NA	NA	NA	NA
TR-4	9	261	87.3	56.1	58.7	75	13.5	6	6.5	<2	NA
TR-4	10	210	21.6	36	34.7	60	11	6	4	<2	NA
TR-5	11A 11B	124	9.9	36.2	64.4	50	11.5 6	4.5	6	11A <2, 11B 4	11A NA, 11B 8.5
TR-5	12	123	28.8	13.6	29	35	14	4	9	<2	NA
TR-6	13	34	34	NA	NA	30	9	4	9	20	24
TR-6	14	2	NA	2	NA	140	9	4	9	36	40
TR-6	15	12	0.1	1.1	0.1	100	9	4	9	24	28
TR-7	16	131	131	NA	NA	40	8.5	5	8.5	10	15
TR-8	17	368	322.9	44.7	0.4	15	8.5	3.5	8.5	16	19.5
TR-11	18	19	19	NA	NA	10	4	2	4	11	13
TR-10	19	48	48	NA	NA	10	5	5	5	7	12
TR-9	20	22	22	NA	NA	35	4.5	3.5	4.5	9	12.5

Notes: Panels 1-3 have been eliminated from the mining plan.

Panels 4-8 are Carney seam,Panels 9 and 10 have the Carney and where it splits into Upper and Lower Carney, and Panels 11-20 are Upper and Lower Carney.
Panels 11 and 12 are primarily under 2ft difference, 11B is 4ft. Average difference.
For Panels 13-18 an average thickness of the interburden was used for these to determine the overburden depth.
For Panels 19 and 20 the borehole drilled in that area was used for the interval information.
Where coal seam splits are less than 2ft. both the upper and lower veins are considered mined with a 1ft. Thick split considered between the veins.

TABLE 3 ESTIMATED NUMBER OF SINKHOLES FOR PANELS 5 AND 6 FOR AVERAGE CARNEY THICKNESS

Panel Depth Range (ft)	Ratio of Depth to Thickness	Panel 5 Surface Area (Acres)	Panel 6 Surface Area (Acres)	Total Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<44	2.7	0.0	0.0	0.0	17.01	0.0
44-87	4.1	4.7	8.9	13.6	8.05	109.1
87-131	6.9	2.1	10.8	12.9	5.47	70.4
131-175	9.6	31.2	14.4	45.5	0.24	10.9
175-218	12.4	14.6	17.2	31.8	0.26	8.3
218-262	14.6	7.5	25.6	33.0	0.06	2.0
262-306	17.9	0.0	0.0	0.0	0.00	0.0
					Total	201

Notes:
1) TR-2 encompasses Panels 5 and 6 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 16ft.

TABLE 4 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 7 FOR AVERAGE CARNEY THICKNESS

Panel Depth Range (ft)	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<32	2.7	0.0	17.01	0.0
32-63	4.1	3.7	8.05	29.9
63-95	6.9	7.1	5.47	38.7
95-126	9.6	2.3	0.24	0.6
126-158	12.4	0.0	0.26	0.0
158-190	14.6	0.0	0.06	0.0
190-221	17.9	0.0	0.00	0.0
			Total	70

Notes:
1) TR-3 encompasses Panel 7 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 11.5ft.

TABLE 5 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 8 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<41	2.7	5.7	17.01	96.6
41-82	4.1	8.0	8.05	64.4
82-124	6.9	7.6	5.47	41.4
124-165	9.6	7.2	0.24	1.7
165-206	12.4	5.5	0.26	1.4
206-247	14.6	1.9	0.06	0.1
247-288	17.9	0.0	0.00	0.0
			Total	206

Notes:
1) TR-3 encompasses Panel 8 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 15ft.

TABLE 6 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 9 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<37	2.7	0.0	17.01	0.0
37-74	4.1	0.0	8.05	0.0
74-111	6.9	73.5	5.47	402.0
111-148	9.6	83.7	0.24	20.1
148-185	12.4	74.5	0.26	19.4
185-223	14.6	28.4	0.06	1.7
223-260	17.9	0.0	0.00	0.0
			Total	444

Notes:
1) TR-4 encompasses Panel 9 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 13.5ft.

TABLE 7 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 10 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<30	2.7	0.0	17.01	0.0
30-60	4.1	1.2	8.05	9.4
60-91	6.9	10.8	5.47	59.3
91-121	9.6	12.0	0.24	2.9
121-151	12.4	42.8	0.26	11.1
151-181	14.6	52.5	0.06	3.2
181-212	17.9	41.1	0.00	0.0
			Total	86

Notes:
1) TR-4 encompasses Panel 10 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 13.5ft.

MEA

TABLE 8 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 11A FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<32	2.7	0.0	17.01	0.0
32-63	4.1	0.0	8.05	0.0
63-95	6.9	2.3	5.47	12.6
95-126	9.6	9.0	0.24	2.1
126-158	12.4	14.2	0.26	3.7
158-190	14.6	38.0	0.06	2.3
190-221	17.9	0.0	0.00	0.0
			Total	21

Notes:
1) TR-5 encompasses Panel 11A based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 11.5ft.

TABLE 9 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 11B FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<16	2.7	0.0	17.01	0.0
16-33	4.1	0.0	8.05	0.0
33-49	6.9	0.0	5.47	0.0
49-66	9.6	1.4	0.24	0.3
66-82	12.4	0.8	0.26	0.2
82-99	14.6	0.9	0.06	0.1
99-115	17.9	1.1	0.00	0.0
			Total	1

Notes:
1) TR-5 encompasses Panel 11B based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 6ft.

TABLE 10 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 12 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<38	2.7	0.0	17.01	0.0
38-77	4.1	6.4	8.05	51.1
77-115	6.9	16.0	5.47	87.8
115-154	9.6	26.0	0.24	6.2
154-192	12.4	18.9	0.26	4.9
192-231	14.6	5.8	0.06	0.3
231-269	17.9	0.0	0.00	0.0
			Total	151

Notes:
1) TR-5 encompasses Panel 12 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 14 ft.

TABLE 11 ESTIMATED NUMBER OF SINKHOLES FOR PANELS 13, 14 AND 15 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Panel 13 Surface Area (Acres)	Panel 14 Surface Area (Acres)	Panel 15 Surface Area (Acres)	Total Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<25	2.7	0.0	0.0	0.0	0.0	17.01	0.0
25-49	4.1	0.2	0.0	0.0	0.2	8.05	1.8
49-74	6.9	2.0	0.0	0.0	2.0	5.47	11.1
74-99	9.6	6.1	0.0	0.0	6.1	0.24	1.5
99-124	12.4	2.4	0.0	0.0	2.4	0.26	0.6
124-148	14.6	0.7	0.0	4.2	4.8	0.06	0.3
148-173	17.9	0.0	0.1	3.2	3.3	0.00	0.0
						Total	16

Notes:
1) TR-6 encompasses Panels 13, 14 and 15 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 9 ft.

TABLE 12 ESTIMATED NUMBER OF SINKHOLES FOR PANELS 16 AND 17 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Panel 16 Surface Area (Acres)	Panel 17 Surface Area (Acres)	Total Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<23	2.7	0.0	0.0	0.0	17.01	0.0
23-46	4.1	2.5	58.4	60.9	8.05	489.9
46-70	6.9	79.6	58.4	138.0	5.47	755.0
70-93	9.6	37.4	59.6	97.0	0.24	23.3
93-117	12.4	11.5	79.8	91.2	0.26	23.7
117-140	14.6	0.0	61.9	61.9	0.06	3.7
140-163	17.9	0.0	29.7	29.7	0.00	0.0
					Total	1296

Notes:
1) TR-7 and TR-8 encompass Panels 16 and 17, respectively based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 8.5 ft.

TABLE 13 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 18 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<11	2.7	0.0	17.01	0.0
11-22	4.1	0.0	8.05	0.0
22-33	6.9	0.0	5.47	0.0
33-44	9.6	9.7	0.24	2.3
44-55	12.4	9.4	0.26	2.4
55-66	14.6	0.0	0.06	0.0
66-77	17.9	0.0	0.00	0.0
			Total	5

Notes:
1) TR-11 encompasses Panel 18 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 4 ft.

TABLE 14 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 19 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<14	2.7	0.0	17.01	0.0
14-27	4.1	0.0	8.05	0.0
27-41	6.9	23.2	5.47	127.0
41-55	9.6	9.3	0.24	2.2
55-69	12.4	11.8	0.26	3.1
69-82	14.6	3.6	0.06	0.2
82-96	17.9	0.0	0.00	0.0
			Total	133

Notes:
1) TR-10 encompasses Panel 19 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 5ft.

TABLE 15 ESTIMATED NUMBER OF SINKHOLES FOR PANEL 20 FOR AVERAGE CARNEY THICKNESS

Ratio of Depth to Thickness	Ratio of Depth to Thickness	Surface Area (Acres)	Density of Subsidence Features (No./Acre)	No. of Subsidence Features
<12	2.7	0.0	17.01	0.0
12-25	4.1	0.0	8.05	0.0
25-37	6.9	5.6	5.47	30.9
37-49	9.6	3.5	0.24	0.8
49-62	12.4	6.6	0.26	1.7
62-74	14.6	3.3	0.06	0.2
74-87	17.9	2.6	0.00	0.0
			Total	34

Notes:
1) TR-9 encompasses Panel 20 based on MEA Figure 4.3
2) Overburden contours used are found on Addendum D5-4 Exhibit 1
3) Assumed Coal Height of 4.5ft.

ATTACHMENT A

Documents Reviewed

Response to EQC Finding of Facts and Conclusions of Law, WDEQ Comments Round 7 – Brook Mine Permit to Mine Application TFN 6 2/025

Figure 2.3-1 – Carney Seam Pre-mine Potentiometry (Round 7 and Round 9)

Addendum MP-6 – Subsidence Control Plan (Round 7 and Round 9)

Addendum MP-6-11 (Round 8 and Round 9)

Addendum MP-6-12,13,14,15 (Round 7 and Round 9)

Attachment MP-6-A (Round 9)

Mining Plan (Round 8 and Round 9)

Table MP.1-3,4 (Round 7 and Round 9)

Figure MP.1-1,2,3,4,5 (Round 7 and Round 9)(MP.1-5 Removed in Round 9)

Figure MP.4-1,2,3 (Round 7 and Round 9)

Figure MP.2-1,2 (Round 9)

Figure MP.3-1 (Round 9)

Figure MP.9-1 (Round 7 and Round 9)

Mine Plan Exhibits (Round 8 and Round 9)

Index Sheet for Mine Permit Amendments or Revisions (Round 8 and Round 9)

Mining Plan Table of Contents (Round 8 and Round 9)

Exhibit MP.15-1,2 (Round 7 and Round 9)

Brook Mine_New Permit Application_CHIA 39_DRAFT_28Feb2020 (Round 12)

Reclamation Plan (Round 9)

Appendix D5 Topography, Geology and Overburden Assessment (Round 9)

Appendix D6 Hydrology (Round 7 and Round 9)

Addendum MP3 Hydrostatic Units (Round 7 and Round 9)

Brook RD10_Total Submittal_Combined (Round 10)

RAMACO_CARF_2019_GW_Elevations (Round 10)

RAMACO_CARF_2019_GW_Quality_Field (Round 10)

RAMACO_CARF_2019_GW_Quality_Lab (Round 10)

Round 8 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 8 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 9 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 9 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 10 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 10 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 11 Technical Review, DEQ Comments/Cover letter, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, DEQ Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Comments, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Cover Letter, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Submittal, Brook Mine Coal Mine Permit Application, TFN 6 6/025

Round 12 Technical Review, Ramaco Comments Change Index, Brook Mine Coal Mine Permit Application, TFN 6 6/025

ATTACHMENT B

MEA January 23, 2017 Report

January 23, 2017

Ms. Shannon Anderson
Acting Director
Powder River Basin Resource Council
934 Main St.
Sheridan, WY 82801

Re: Brook Mine Permit Application

Ms. Anderson,

As you have requested, I have reviewed the mine application for the proposed Brook Mine by Ramaco, LLC. This proposed mining is located about 8.5 miles north of Sheridan, WY (see Figure 1.1). In my evaluation of the Ramaco mine application, I performed a cursory to detailed review of the following documents:

- Mine Plan
    - Addendum MP-1: Alternative Sediment Control Measures
    - Addendum MP-3: Groundwater Model
    - Addendum MP-6: Subsidence Control Plan
    - Addendum MP-7: Blasting Plan Supplemental Materials
- Appendix D2: History
- Appendix D5: Topography, Geology, and Overburden Assessment (Oct. 2014 and Jul. 2015)
    - Addendum D5-1: Drill Hole Tabulations (State Plane Coordinates)
    - Addendum D5-2: Lithologic and Geophysical Logs

- Addendum D5-3: Geologic Cross-Sections
- Addendum D5-4: Isopach Maps
- Addendum D5-5: Overburden, Roof and Floor Sample Analysis Tables
- Addendum D5-6: WDEQ/LQD Overburden Sampling Frequency Waiver
- Addendum D5-7: Soil Analysis Reports

- Appendix D6: Hydrology
  - Addendum D6-1: HEC-HMS Model
  - Addendum D6-2: Miller Regression Analysis
  - Addendum D6-3: HEC-RAS Model
  - Addendum D6-4: Surface Water Hydrographs
  - Addendum D6-7: Monitor Well Completion Data
  - Addendum D6-8: Pumping Test Report
- Appendix D11: Alluvial Valley Floors
- Bond Estimate
- Reclamation Plan
- Effects of Coal Mine Subsidence in the Sheridan, Wyoming Area, USGS Paper 1164 by C. Dunrud and F. Osterwald, 1980
- Technical Report on the Welch Ranch Coal Fire by E. Heffern, J. Queen, and K. Henke, April 28, 2003
- 2014-2019 Sheridan County, WY Multi-Hazard Mitigation Plan
- USDA Soil Survey of Sheridan County Area, Wyoming

SITE TOPOGRAPHY

The topography of the mine site is shown in Figure 1.2. As seen in Figure 1.2, except for the southeastern “leg” of the application area, the proposed mine site is just north of the meandering east-west Tongue River, with the overall ground surface within this application area draining to the Tongue River. The main drainage features trend NW-SE (e.g. Early Creek, E. Fork Early Creek, Slate Creek, and Hidden Water Creek) approximately conjugate to known fault traces. Between each tributary or drainage incision, the surface elevations reach about 3,840 ft. – 4,100 ft., with relief from the valley of typically 150 ft. to 200 ft. The lowest point is shown at about 1,680 ft. El. at the Tongue River whereas the highest point depicted is centrally located near the north limits of the application area at Elevation about 4,100 ft. In the smaller southeastern “leg” of the application area, the ground basically drains west into Goose Creek or to the north into the Tongue River.

GEOLOGIC CONDITIONS

Within the mine application area, the relevant geologic materials are reported to be weathered to unweathered rock and colluvium from mass wasting. These rock beds belong to the Union Fort Formation of Tertiary age with the coal bearing strata in the lower sequences of the Tongue River Member. See Figure 2.1. Below the Tongue River Member is the Lebo Member which regionally consists of mainly clayey shale.

Mineable heights of the site sub-bituminous coal beds are discontinuous across the site. The main seams that will be mined are the Carney and the lower Masters. The Carney seam splits to the west into the upper and lower Carney benches. This claystone parting is reported to reach a thickness in excess of 30 ft. Where the Carney is vertically continuous, it is stated to be 15 to 20 ft. thick, but when it splits, the upper unit is 2 to 6 ft. thick, and the lower, which typically has better quality, is 4 to 10 ft. thick. The thickness of the underlying Masters, where present, was found to be 4 to 6 ft.

There is also the potential that the overlying Monarch and other more localized coal beds will be mined. It is noted that much of the Monarch seam has been burnt into scoria.

The interburden thickness between the Carney and the Masters has been measured to be from less than 1 ft. at the eastern mine application limit to over 50 ft. As described in the mine application, the vast majority of the coal measures are composed of claystone with fairly localized layers of moderately to well cemented sandstone to siltstone lenses. In other words, the floor of the mineable coal seams is claystone. The Lebo member which underlies the Master Coal measures is described as mudstone.

The application area is known to be faulted. Normal faults are reported which trend NE-SW causing a horst and graben structure across the mine area, the dip of this faulting, or the character of it’s broken zone are not known. Based on the surface drainage features conjugate structure may also be present. The dip of the beds in the faulted blocks is reported to be about 2 degrees in the south-southeast direction.

GEOTECHNICAL CONDITIONS

From review of the relevant portions of the permit application, all the reported geotechnical laboratory results for the coal measures in the reserve are summarized in Table 3.1. As can be seen here, there has been scant few rock mechanics testing. And consequently no sense of the important engineering properties and their spatial variations of the relevant coal measures through the reserve can be realistically achieved. The rock mechanics testing should include:

- Moisture content
- Liquid and plastic limits determinations
- Rock durability
- Tensile strength
- Uniaxial compression or Point load strengths
- **Consolidated-drained** triaxial strength
- Swell potential

Furthermore, from a geotechnical engineering standpoint, the rock descriptions for the borings drilled are wholly inadequate. This includes:

- No RQD measurements
- No fracture descriptions – are fissures or slickensides present and at what frequency?
- No to inadequate (uncodified) hardness descriptions
- No codified description of rock classifications

From a geotechnical engineering perspective, there is a severe concern given that the vast majority of the coal measures are described as claystone. Claystone represents very poor mine roof and floor conditions in addition to highwall stability problems. Fine-grained rocks are likely to significantly reduce in strength over time as they swell/soften and deteriorate (Marino and Osouli, 2012). Also, there appears to be mischaracterization as some of the reported claystone as it is described to be fissile, which indicates bedding (not a non-bedded rock).

To properly understand the engineering material nature of fine-grained rocks, sufficient testing of the rock plasticity (Atterberg Limits) and rock durability should be performed (Marino and Osouli, 2012).

MINE PLAN

Ramaco plans to mine with the reserve area mainly in two coal seams. They are the Carney and Masters coals. In the western part of the reserve, the Carney coal seam splits into upper and lower beds. Because these mineable beds are covered, Ramaco plans to create highwalls to expose them by excavating mainly slots or areas by strip mining. Once the mineable seam(s) are exposed, they will be extracted utilizing a remote-controlled continuous miner and conveyor system. An illustration of this proposed highwall operation was provided by Ramaco in Figure 4.1.

The plan showing the areas of proposed mining are depicted in Figure 4.2. This plan shows the blocks of highwall mining and associated strip mining areas. In Figure 4.3, the delineated coal blocks have been numbered for future reference from 1 to 20 east to west. As noted in the application, Ramaco plans to mine essentially from east to west.

The coal blocks will be mined from benches along the highwall by driving parallel entries into the highwall face apparently perpendicular to the highwall. A remote continuous miner system will be utilized to drive the rooms to depths of up to 2,000 ft. The mining equipment that will be used is an ADDCAR highwall mining system with accuracy of 0.1m in 384m of penetration. However, potentially more significant in determining the actually cut pillar widths is the azimuth accuracy which is not discussed. Using this continuous miner, it is noted that typical extraction heights of 30 in. to 28 ft. can be achieved.

The proposed room and pillar configuration is depicted in Figure 4.4. As can be seen in Figure 4.4, there is no definitive geometry stipulated in the application as much of the identified dimensions are qualified. Using the "typical" web pillar widths and room width, the panel extraction ratio would vary from 59% to 70% in the panels.

Ramaco also states that where multiple coal seams will be mined in a block the pillars will be stacked. With apparently the parallel entries of about the same width, this means the pillar width would be the same for all seams of different thickness. Ramaco states the pillar width will be determined by the seam with the greater thicknesses [MP-6-7].

In order to better understand the ground conditions in the areas of proposed mining, the mining layout given in Figure 4.3 has been superimposed over the various isopach exhibits for the Carney and Masters seams provided in the mine application. These drawings are shown in Figures 4.5 to 4.12. Also, the mine block areas had been delineated on the various geologic cross-sections drawn by Ramaco across the site (see Figure 4.3). The modified cross-sections showing the mine block locations are shown in Figures 4.13 to 4.24. From this reported information, the Dietz, Monarch, Carney, and Masters related conditions per block have been summarized in Table 4.1.

Other considerations are noted below.

- There is no discussion that could be found on reclamation of the mine openings in the highwalls which are left after an area is complete. Depending upon the seal (if any) and dip of the coal, groundwater (and runoff if not sealed) can pool in the entry. Also, if any of these areas are contoured, these entries, as a source of water, can have a detrimental effect of the stability of the reclaimed slope.

- The mine application notes oil and gas wells are present. There is no discussion that could be found on how these wells will be addressed during mining, or how they will be handled if the well is mislocated or was unknown when encountered during mining.

- Ramaco has not addressed the potential for the significant portion of the pillar being composed of claystone from mining in the blind where the coal has significantly variable thickness, or clay parting(s).

MINE STABILITY ANALYSIS

An integral part of assessing the subsidence potential for any proposed coal mining is the determination of whether the coal mine structure will be stable in the short and long term. The mine application, however, provides no calculations of the planned and expected roof, pillar, or floor conditions. In fact, the only governing criteria provided is that “support pillars will be designed to have a width equal to or exceeding the maximum extraction thickness” [MP-6-4]. Ramaco states that this is based on the NIOSH pillar stability program and the recommended stability factor (i.e. safety factor) and that “pillar dimension will also be in accordance with Brook Mine’s Ground Control Plan approved by MSHA”. Contact with MSHA found that no ground control plan has been filed. They stated that such a plan applies to open pit conditions and thus would not address pillar dimensions (although the NIOSH pillar program manual for highwall mining notes it is part of the MSHA ground control plan). Moreover, approval from MSHA (whose responsibility is safety) is irrelevant as the concern here is land subsidence.

In stating the pillar width to height ratio will be one or greater, none of the input assumptions or output for the pillar dimension criteria have been provided to evaluate how this criterion was arrived at. For example, the assumed coal strength for the various subbituminous seams (without any substantial test data), assumed coal extraction, and the assumed overburden depth are not known. Also, there is no discussion in the mine application of the effect of multiple seam mining (including overlying or subjacent old works presence) [NISOH ARMPS-HWM]. Moreover, the proposed utilization by Ramaco of the coal tensile strength to assess pillar strength is not standardly done in the industry [D5-10].

There is no governing roof and floor design criteria on what will dictate the barrier and web pillar width and spacing, and panel width to avoid complete overburden instability, based on the variable ground/mining conditions which may be encountered (see Figure 5.1). This is especially problematic given the reported very poor roof and floor consisting mostly of claystone although resistance augmented siltstone and sandstone zones exist there locally (see Figure 4.13 to 4.24).

With the poor identification of the following conditions, it is impossible to obtain a reasonable understanding of the short and long term stability of the proposed mining (or even the slope/highwall). This includes:

- More definitive room-and-pillar layout.

- Sufficient understanding of the engineering properties of the roof, pillar, and floor materials.

- Sufficient understanding of the geologic structure including the nature and orientation (strike and drip) of all faults and shears; and fissure/slickenside concentrations.

An idea of the mine stability conditions can be obtained, however, from the available information. From Table 4.1, mine depths of over 400 ft. are planned with extraction heights reaching 18+ ft. Given the mine depths and planned panel extraction ratios, tributary pillar pressures up to close to 1,300 psi will exist. Even assuming a higher bituminous coal strength at pillar width to heights of one (as proposed), the stability factor calculates to an unacceptable value of less than one at this pillar pressure where the panels are sufficiently wide.[1] This was calculated using the Mark-Bieniawski pillar strength equation, which is the same one used by Ramaco and cited by MSHA. Also, this pillar bearing load will be well in excess of the reported claystone roof and floor (Marino and Bauer, 1989).

Other concerns which have not been addressed but can play a role in the stability of the proposed mine workings include:

- The effect of flooding or pooling of groundwater. Saturation or repeated cycles of wet and dry of the clay roof, pillar (partings) and floor can dramatically effect it's inplace strength, and subsequently causing failure. Inflows of groundwater are

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[1] Note the MSHA criteria for pillar strength were based on pillar heights of 7 ft. or less whereas 18 ft. heights are proposed.

noted by Ramaco from drainage and where aquifers are saturated [MP-45]. Although a 500 ft. coal barrier is planned between the old works and the Brook Mine [MP67-8], there is also the potential that the proposed mining can be inundated from the presence of adjacent old Carney workings that may contain water. This risk is attributed to unmapped workings and unknown geologic structures. Note on Figure MP-6.1-1, the old works are not shown buffered with barrier pillars 500 ft. in width. Moreover, the drainage of pool or flooded old workings can reactivate or cause additional land subsidence in those areas.

- Effect of stacking of pillars on stability with change in interburden thickness; and the accumulated void height and the effect on chimney subsidence.

- As noted in the permit application, a clay parting cuts the Carney seam into upper and lower benches. There is not discussion or analysis of when the parting becomes sufficiently thick to cause pillar instability and consequently resort to mining the upper or lower bench. How the remote continuous miner “blindly” cuts just coal is not discussed.

Although not a mine subsidence concern, there can be serious slope/highwall instability given the extent of claystone throughout the reserve in addition to the evidence of faulting. The proposed benches for support of mining equipment and personnel are also similarly subjected to instability, especially since these claystone areas will tend to collect slope runoff and minewater.

SUBSIDENCE POTENTIAL

The subsidence of the proposed Brook Mine is discussed in the Subsidence Control Plan of the mine application. Subsidence can basically come in the form of pits (sinkholes) and sags. Pits form on the ground surface from the complete collapse of the overburden into a mine entry. Sags are mine subsidence events which are bowl-shaped depressions. They are caused by overburden collapse in the mine entry, a pillar failure, and a bearing failure in the roof or floor. Entry-induced sag events tend to be significantly smaller than those from a pillar or bearing failure. (See MEA Engineering UPDATE Issue 14).

The pit subsidence over the old workings in the mine application area can be seen in the aerial photographs as shown in Figure 7.1 to 7.5. These photographs show areas of more isolated to intense patterns of pit subsidence indicating poor overburden roof conditions. This is consistent with the vast majority of the rock overburden described as claystone without resistant durable interbeds. There also appears to be some subsidence-induced slop instability (i.e. slump features in Area 2, Figure 7.2). The mine depth is estimated to reach up to 160 ft. in visible subsidence areas. Broader subsidence events (i.e. sags) from pillar or pillar bearing failure or mine fire are not noticeable on aerials photographs examined but also are reported in the region.

Ramaco's subsidence analysis treats entry-induced subsidence (i.e. chimney subsidence) by analyzing pit subsidence over the historic Mine No. 44 by utilizing a roof stoping equation by Dyne, 1998 for a four-way equal width room intersection which is provided below.

$$z = 12/ (\pi (k-1) (d_{base}^2 + d_{surf}^2 + d_{base}d_{surf})) (\pi/12t (d_{base}^2 + D^2 + Dd_{base}) - ((D-w) /6 \tan \theta) (D^2 \arccos (w/D) = D^2/2 \sin (2\arccos (w/D)) - \pi D^2/4 + w^2))$$

The equation is based on the following variables:

- w = width of mine rooms (ft.)
- t = height of seam (ft.)
- k = bulking factor = V_B/V where V is the initial volume and $V_{\mathbf{B}}$ is the volume of rubble
- θ = angle of repose of caved rock within mine room
- d_{base} = diameter of collapse-chimney at base (ft.)
- d_{surf} = diameter of collapse-chimney at surface (ft.)
- D = diameter of caved rock foot print on mine room floor (ft.)

Ramaco "confirms" that with use of the above relationship that this relationship is representative of the observations of pit subsidence to a depth of 150 ft.[2] by assuming certain parameter values. Ramaco does not, however, use this same stoping relationship which was 'confirmed' based on historic pit subsidence to actually assess

[2] Using assumed parameter values by Ramaco, z calculates to 124 ft. and 145 ft. for chimney diameters/roof spans of 25 ft. and 20 ft., respectively.

the stoping potential of the proposed mining. It is only stated that the “proposed highwall mining opening widths of 11 to 11.5 ft. are significantly less than” the historic Mine No. 44 [MP-6-7]. When assuming the above chimney subsidence relationship, with intersecting entries were assumed at 11-11.5 ft., as proposed, and considering the same Ramaco assumed parameter values, z (or the stoping depth) becomes 219-227 ft. However, assuming a four-way equal room width intersection, as in the above stoping equation, does not represent any of the actual pit locations as indicated by the mine map.

Considering pit subsidence along entries without intersections, which is more representative of the underlying historic subsidence conditions, and assuming a repose angle of slaked claystone cavein of 20° and the other Ramaco assumptions, a bulk factor of 1.33 is calculated. Under the proposed mining conditions and considering this back-calculated bulking factor, the potential stoping height (or mine depth) becomes about 225 ft. Clearly, with the claystone overburden of limited reported resistant, durable beds, reported Carney thickness of 15-20 ft. (in lieu of the assumed thickness of 14 ft.), and greater mine depths experiencing pit subsidence reaching up to about 160 ft. (see Figures 7.1 to 7.5), there is a serious risk of surface subsidence from roof collapse in the proposed mining. Also, Ramaco does not address the proposed stacking of mine entries (i.e. pillar stacking) effect on the upward chimney propagation. Clearly the accumulated void height could produce greater exposure to land surface subsidence.

Although there is no substantial geotechnical exploration or testing or analyses that were, or could be performed - from our experience with the claystone roof and floor, the proposed mining can result in sag subsidence. Pillar failure can also result in sag subsidence. Calculations and assumptions made by Ramaco to demonstrate that short and long term failure from pillar crushing are not provided. Ramaco asserts that pillars with width to height ratios in excess of one are adequate without any substantial coal strength or clay parting data and further states that an approved MSHA-approved ground control will be obtained. This statement is “putting the cart before the horse” when this is a requirement of the subsidence control plan. Moreover, the ground control that is required by MSHA will likely not include mine stability analysis as highwall mining does not require miner ingress.

SUMMARY AND CONCLUSIONS

As requested by the Powder River Basin Resource Council, MEA has performed a subsidence engineering review of the proposed Brook Mine application submitted by Ramaco, LLC. This investigation primarily consisted of examination and evaluation of pertinent sections of the application to assess the subsidence potential of the proposed plan. The findings from this investigation are provided immediately below, however this report should be read in its entirety to obtain a complete understanding of its contents.

1. The proposed Brook Mine is located about 8.5 miles north of Sheridan, WY. The mine plans to mine primarily two sub-bituminous coal seams. These seams are the Carney and the underlying Masters. The Carney Seam is reported to split in

the western half of the application area into upper and lower beds. The clay parting between the upper and lower beds is said to reach more than 30 ft.

2. The coal will be extracted primarily by highwall mining methods. The highwalls will be created by strip mining slots or areas.

3. Based on the reported data, for the Carney, Masters, and other overlying seams, the mining depth is expected to range from near the surface to about 420 ft. with extraction heights that can range as low as 2.5 ft. and exceed 18 ft.

4. The vast majority of the associated coal measures are described as claystone with isolated interbeds of sandstone/siltstone. These coarser grained interbeds are laterally discontinuous but where present exist up to a thickness of 36 ft.

5. The proposed highwall mining is expected to result in 11-11.5 ft. wide parallel entries up to 2,000 ft. into the highwall face with panel extraction ratios of 60 to 70%. Given this range of extraction and mine depth, tributary pillar pressures up to close to 1,300 psi can be expected.

6. A detailed and advanced subsidence engineering analysis is required given the reported geologic and mining conditions. However, the mine subsidence potential investigation provided in the mine application is wholly inadequate and thus renders it impossible to perform an adequate peer review. Of most particular

concern is: 1. the lack of codified rock mass classifications, geologic structure, and geotechnical properties of the relevant coal measures; 2. essentially no short and long term mine stability analyses of all potential failure modes that can lead to surface subsidence; and 3. no appropriate examination of risk, severity, and types of potential subsidence.

7. Given the pervasive extent of claystone reported above, throughout, and below the proposed mining interval, there is serious concern for short and long term mine instability. There are a number of problematic conditions which are discussed above.

8. There is a massive amount of surface subsidence in the area at mine depths similar to that proposed. Based on the reported data, chimney subsidence analyses, and examination of historic air photos in the area, both sag and pit subsidence would be expected at the Brook Mine.

If you have any questions, please don't hesitate to contact me.

Sincerely,

Professional Engineer (Civil)
GENNARO G. MARINO
PE 12993
Date 1/23/17
WYOMING

Gennaro G. Marino, Ph.D., P.E., D.GE
President

Enclosures:

FIGURE 1.1 LOCATION OF PROPOSED MINING

FIGURE 1.2 LOCATION OF MINE APPLICATION AREA FOR THE PROPOSED BROOK MINE SUPERIMPOSED ON QUAD TOPO MAP

FIGURE 2.1 GEOLOGIC COLUMN FOR PROPOSED MINE SITE (SEE P. D5-F4)

FIGURE 4.1 ILLUSTRATION OF PROPOSED HIGHWALL MINING OF COAL VIA STRIP-MINED TRENCH EXCAVATIONS (SEE P. MP-F2)

FIGURE 4.2 PROPOSED MINE PLAN (SEE EXHIBIT MP.15-1)

FIGURE 4.3 PLANNED TRENCH AND COAL BLOCK AREAS WITH FAULTS AND CROSS SECTION LINES

FIGURE 4.4 PROPOSED HIGHWALL MINING ROOM AND PILLAR CONFIGURATION (SEE P. MP-F3)

FIGURE 4.5 CARNEY COAL SEAM OVERBURDEN ISOPACH MAP (UPPER CARNEY WEST OF CARNEY SPLIT) WITH PROPOSED MINE LAYOUT

FIGURE 4.6 CARNEY COAL SEAM THICKNESS ISOPACH EAST OF SEAM SPLIT WITH PROPOSED MINE LAYOUT

FIGURE 4.7 UPPER CARNEY COAL SEAM THICKNESS ISOPACH MAP WEST OF CARNEY SEAM SPLIT WITH PROPOSED MINE LAYOUT

FIGURE 4.8 UPPER AND LOWER CARNEY COAL SEAM INTERBURDEN ISOPACH MAP, WEST OF SEAM SPLIT WITH PROPOSED MINE LAYOUT

FIGURE 4.9 LOWER CARNEY COAL SEAM THICKNESS ISOPACH MAP, WEST OF SEAM SPLIT WITH PROPOSED MINE LAYOUT

FIGURE 4.10 CARNEY AND MASTERS COAL SEAM INTERBURDEN ISOPACH MAP WITH PROPOSED MINE LAYOUT

FIGURE 4.11 MASTERS COAL THICKNESS ISOPACH WITH PROPOSED MINE LAYOUT

FIGURE 4.12 MASTERS COAL BOTTOM ELEVATION ISOPACH WITH PROPOSED MINE LAYOUT

REFERENCES

Dunrud, C. Richard., and Frank W. Osterwald, 1980. Effects of Coal Mine Subsidence in the Sheridan, Wyoming Area. Washington: U.S. Govt. Print. Off.

Dyne, L.A., 1998. The Prediction and Occurrence of Chimney Subsidence in Southwestern Pennsylvania. Virginia Polytechnic Institute and State University, January, 1998.

Marino, G. G., and Bauer, R. A., 1989, Behavior of Abandoned Room and Pillar Mines in Illinois, Int'l Journal of Mining and Geological Engineering, 11 pp.

Marino, G. G. and Osouli, A., 2012, The Influence of Softening on the Mine Floor Bearing Capacity: A Case History. Journal of Geotechnical and Geoenvironmental Engineering. In-Press.

FIGURE 1.1 LOCATION OF PROPOSED MINING

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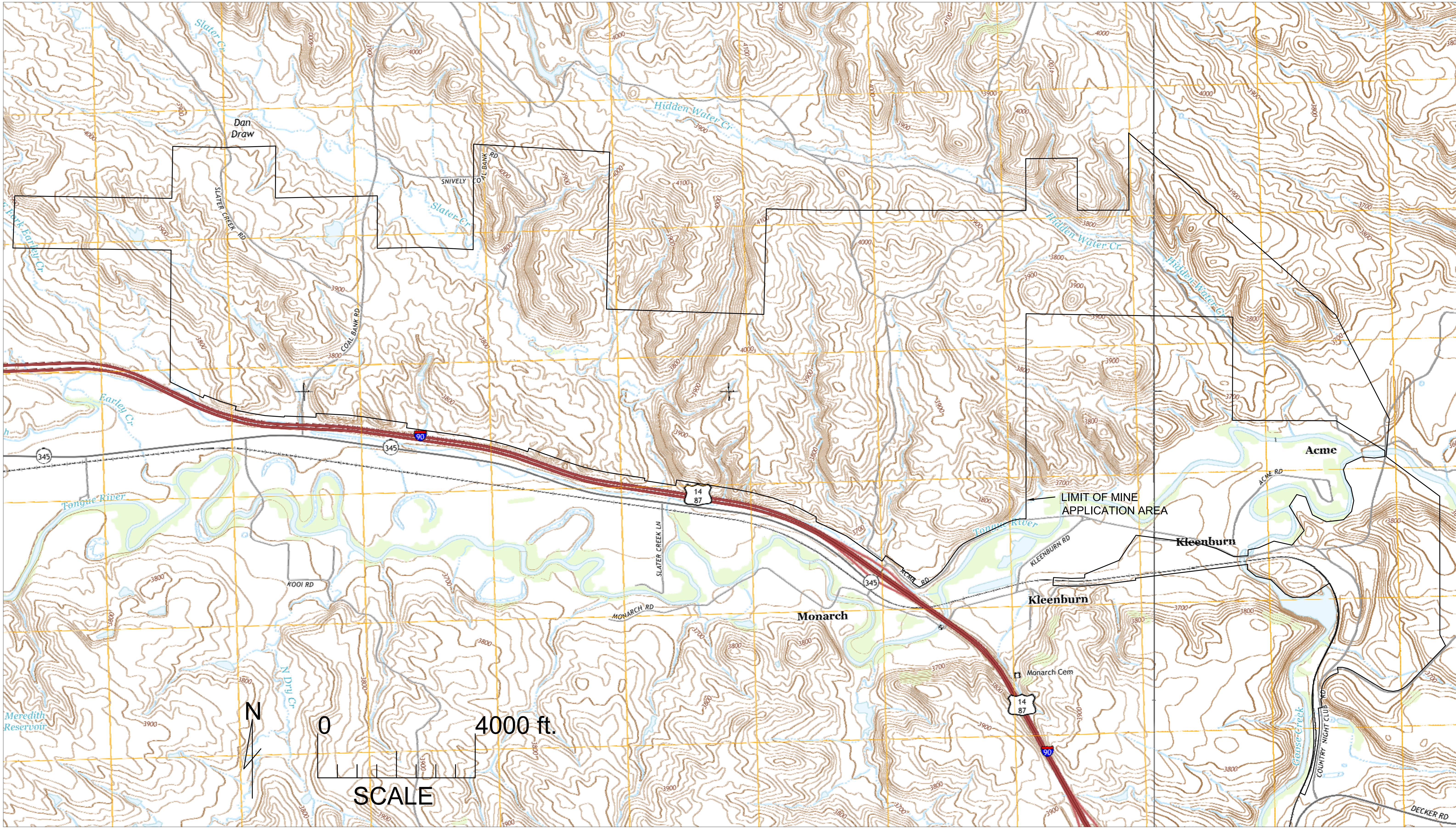

FIGURE 1.2 LOCATION OF MINE APPLICATION AREA FOR THE PROPOSED BROOK MINE SUPERIMPOSED ON QUAD TOPO MAP

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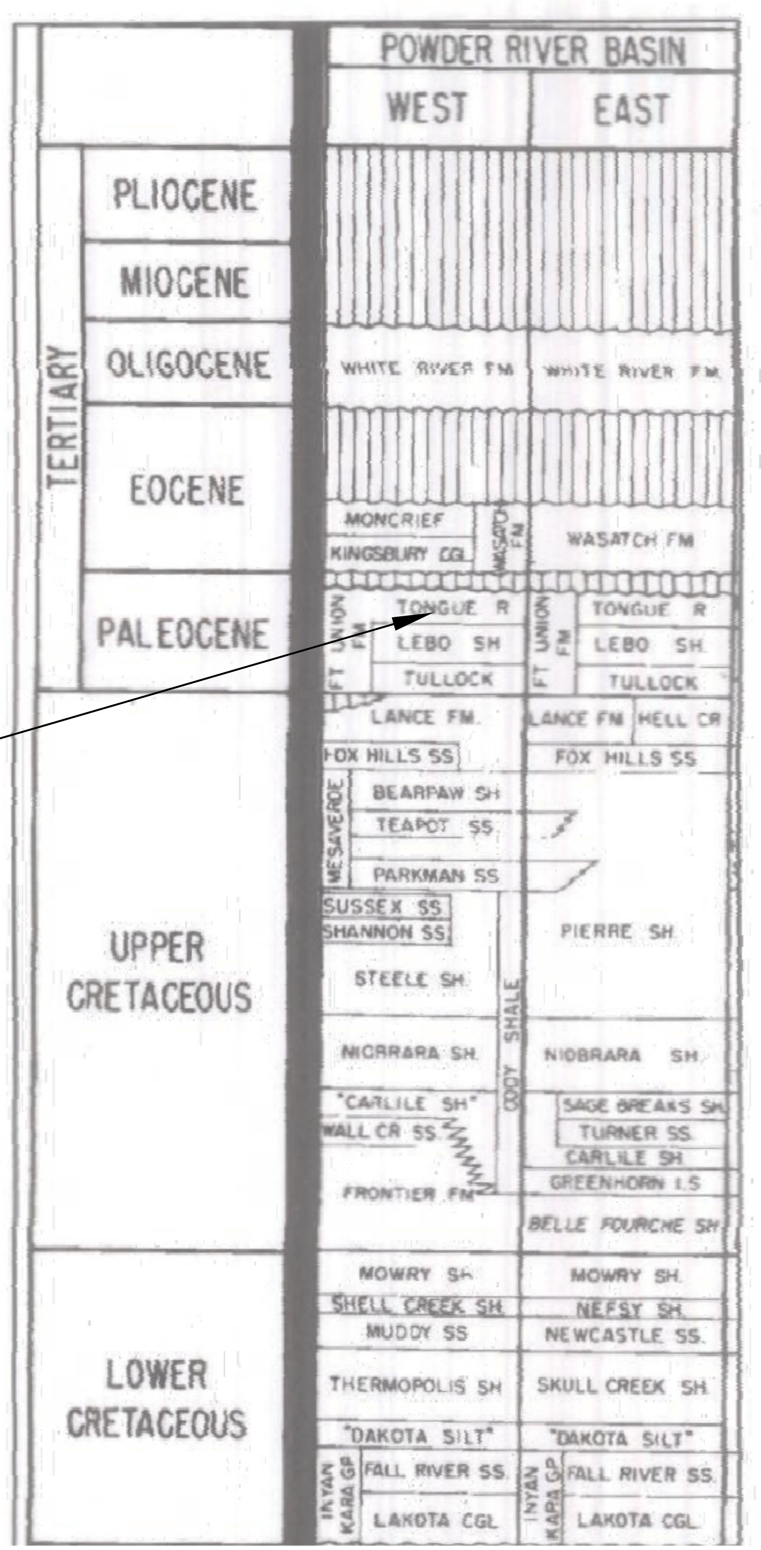

Carney lies above the Masters and "generally mark the bottom of the Tongue River Member" p. D5-10

FIGURE 2.1 GEOLOGIC COLUMN FOR PROPOSED MINE SITE (SEE P.D5-F4)

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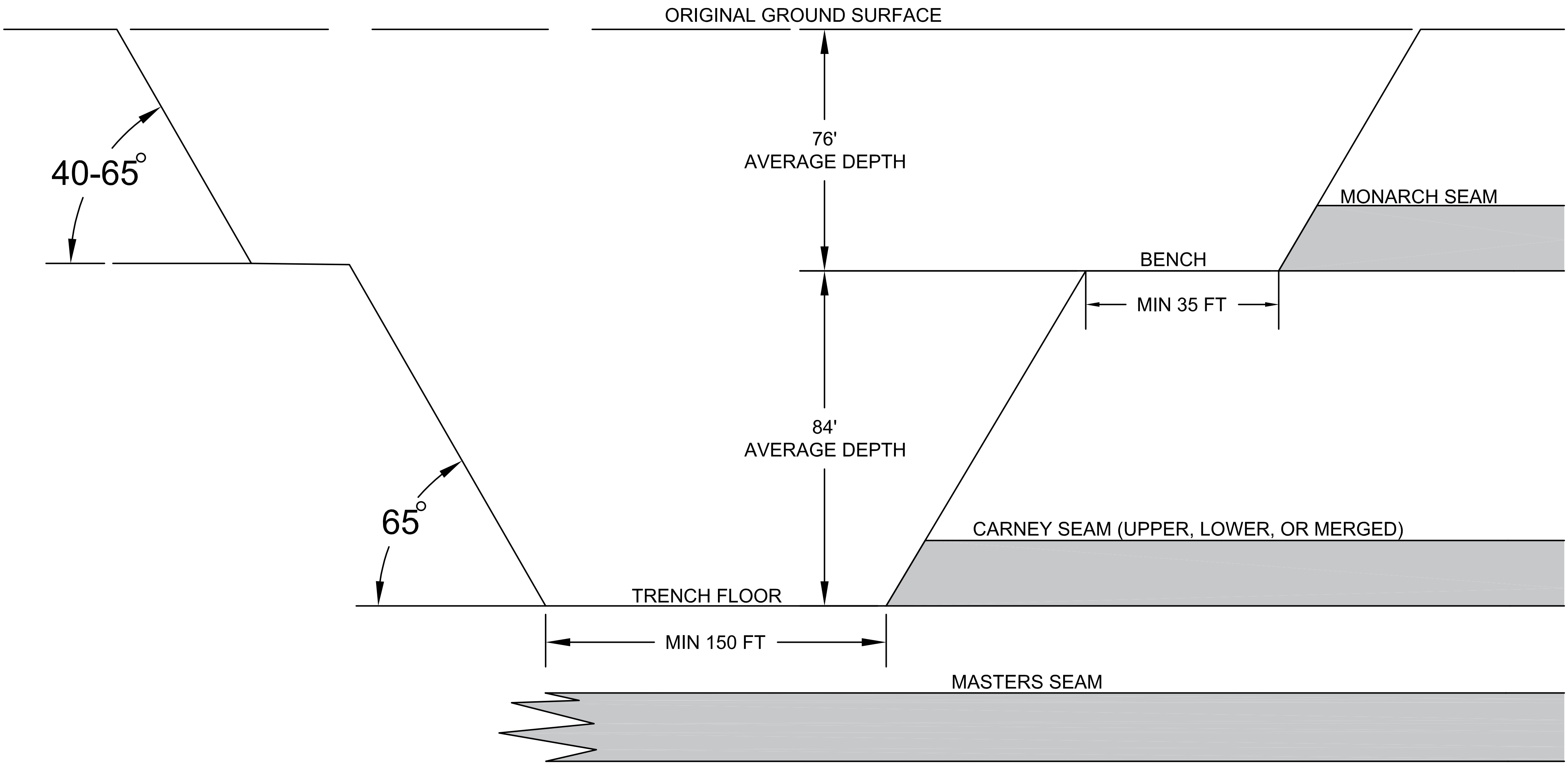

FIGURE 4.1 ILLUSTRATION OF PROPOSED HIGHWALL MINING OF COAL VIA STRIP-MINED TRENCH EXCAVATIONS (SEE P. MP-F2)

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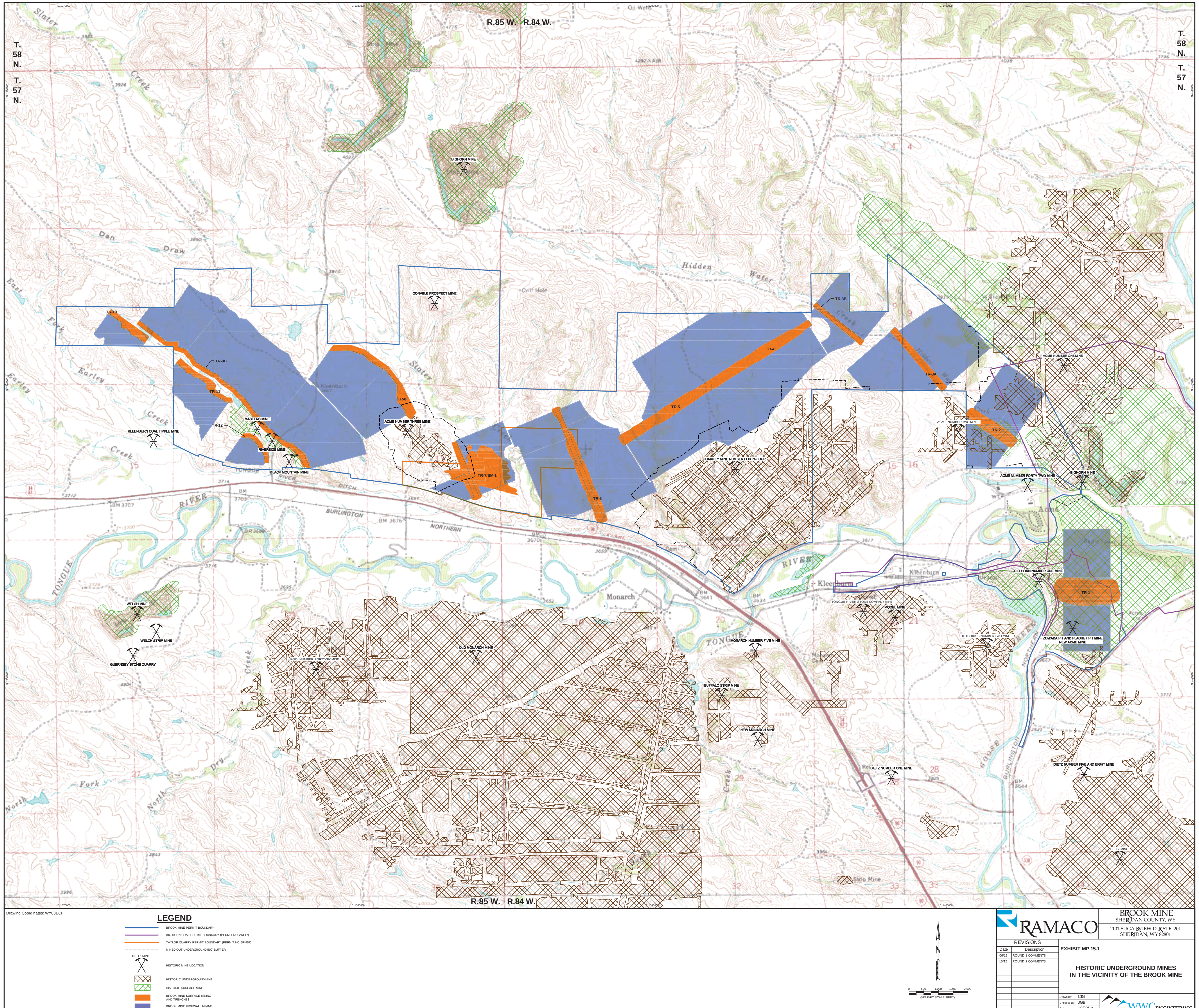

FIGURE 4.2 PROPOSED MINE PLAN (SEE EXHIBIT MP.15-1)

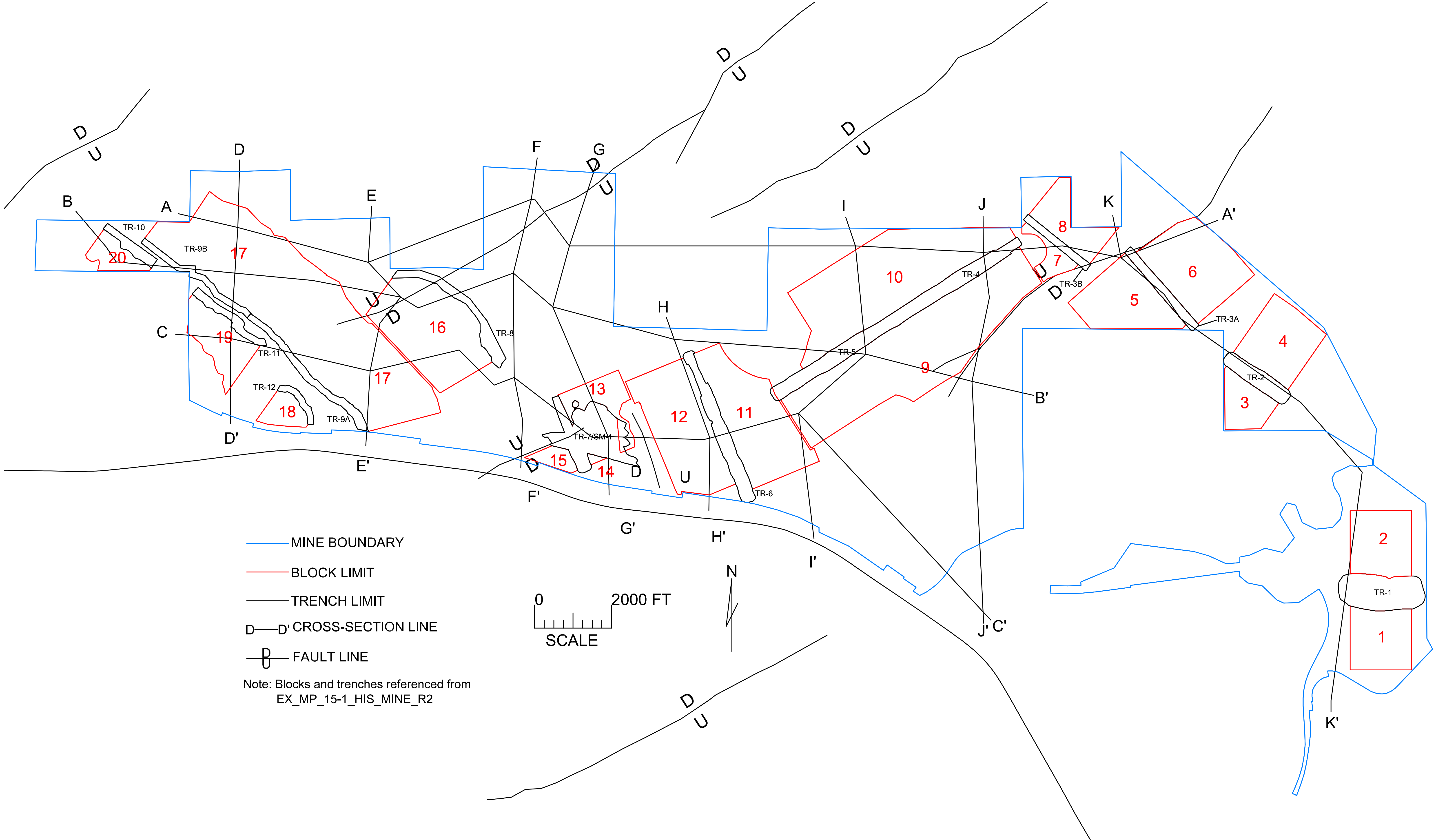

FIGURE 4.3 PLANNED TRENCH AND COAL BLOCK AREAS WITH FAULTS AND CROSS SECTION LINES

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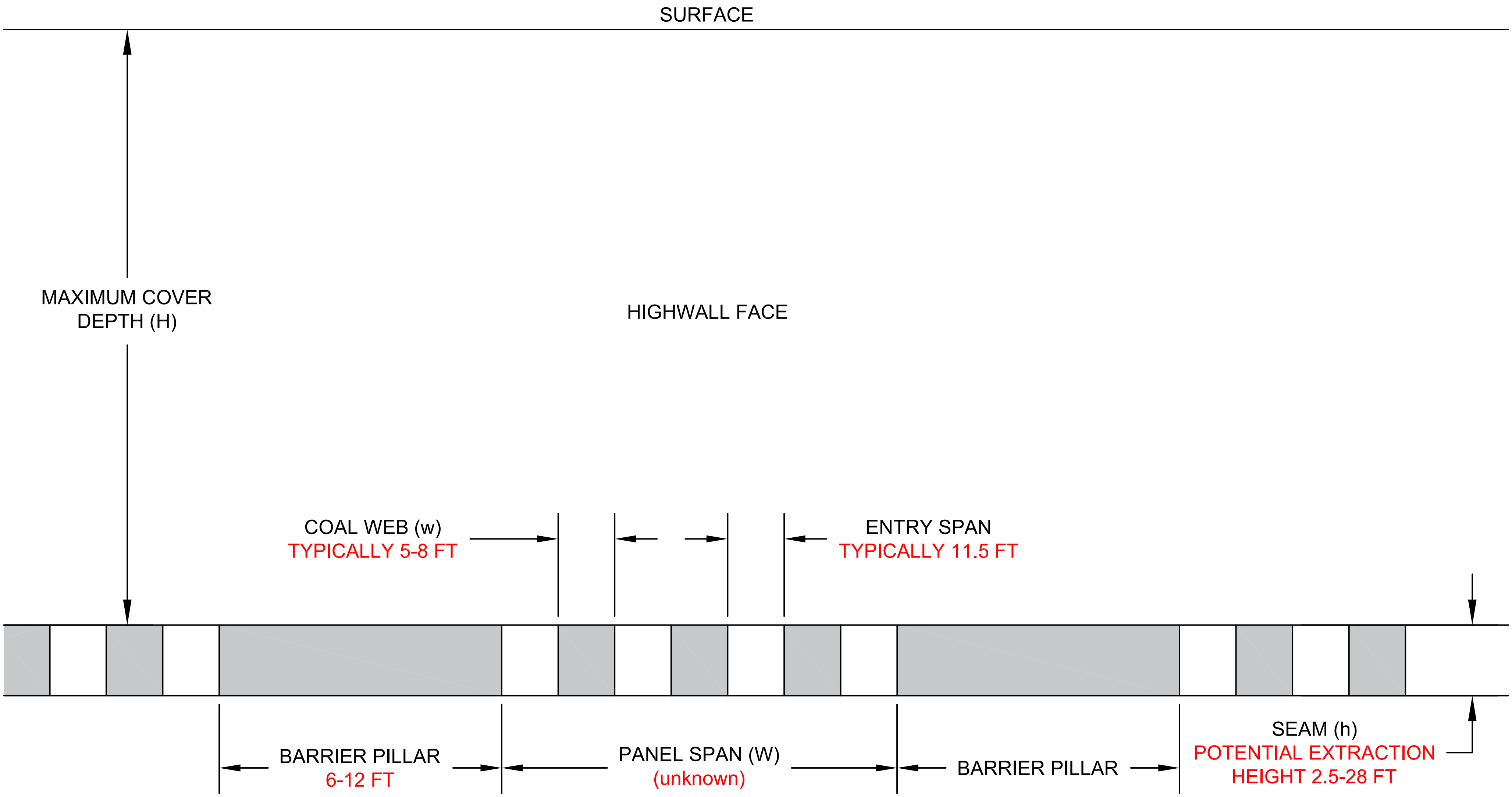

NOMENCLATURE FOR GUIDELINES - HIGHWALL MINING

NOT TO SCALE

FIGURE 4.4 PROPOSED HIGHWALL MINING AND PILLAR CONFIGURATION (SEE P. MP-F3)

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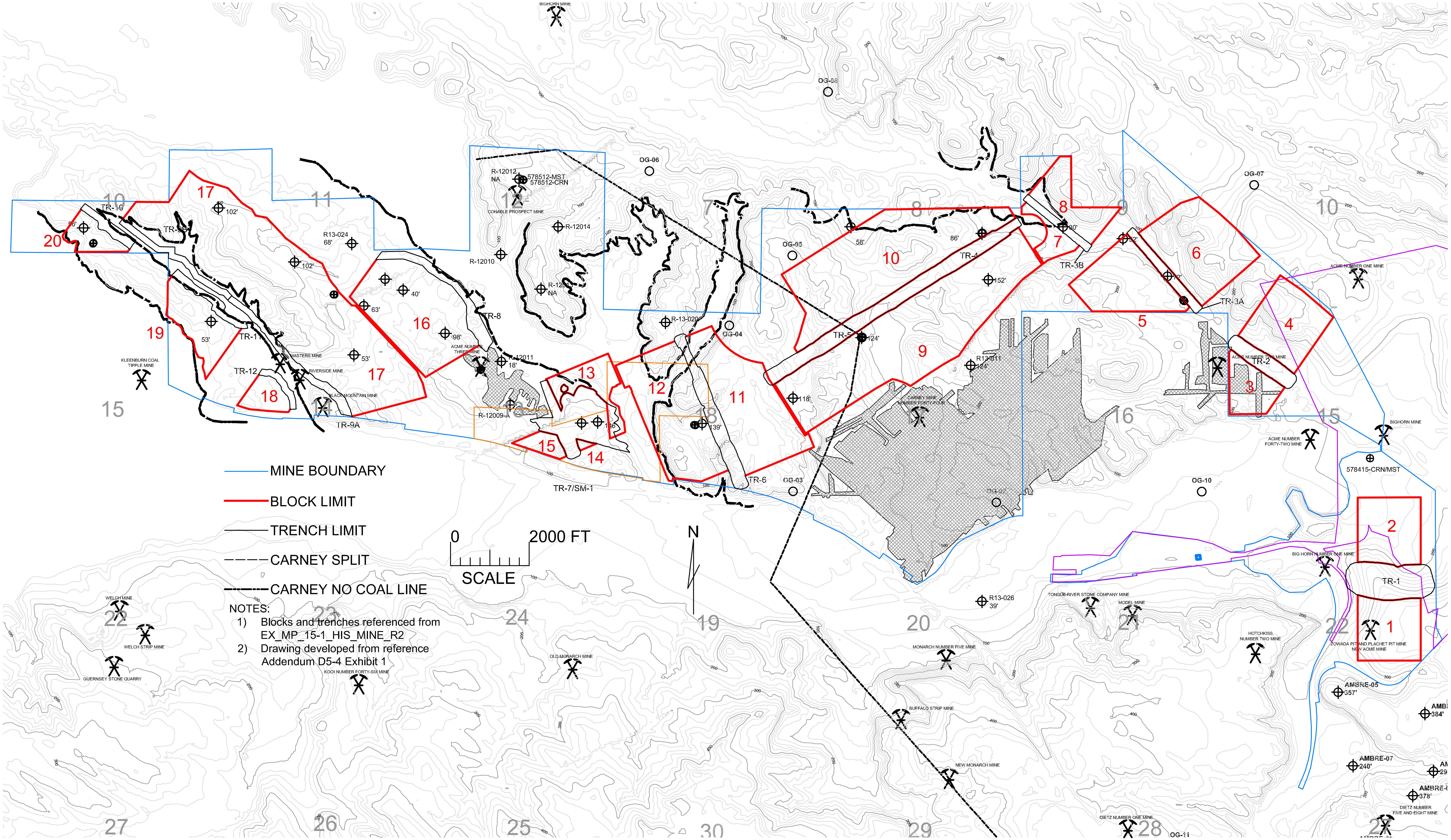

FIGURE 4.5 CARNEY COAL SEAM OVERBURDEN ISOPACH MAP (UPPER CARNEY WEST OF CARNEY SPLIT) WITH PROPOSED MINE LAYOUT

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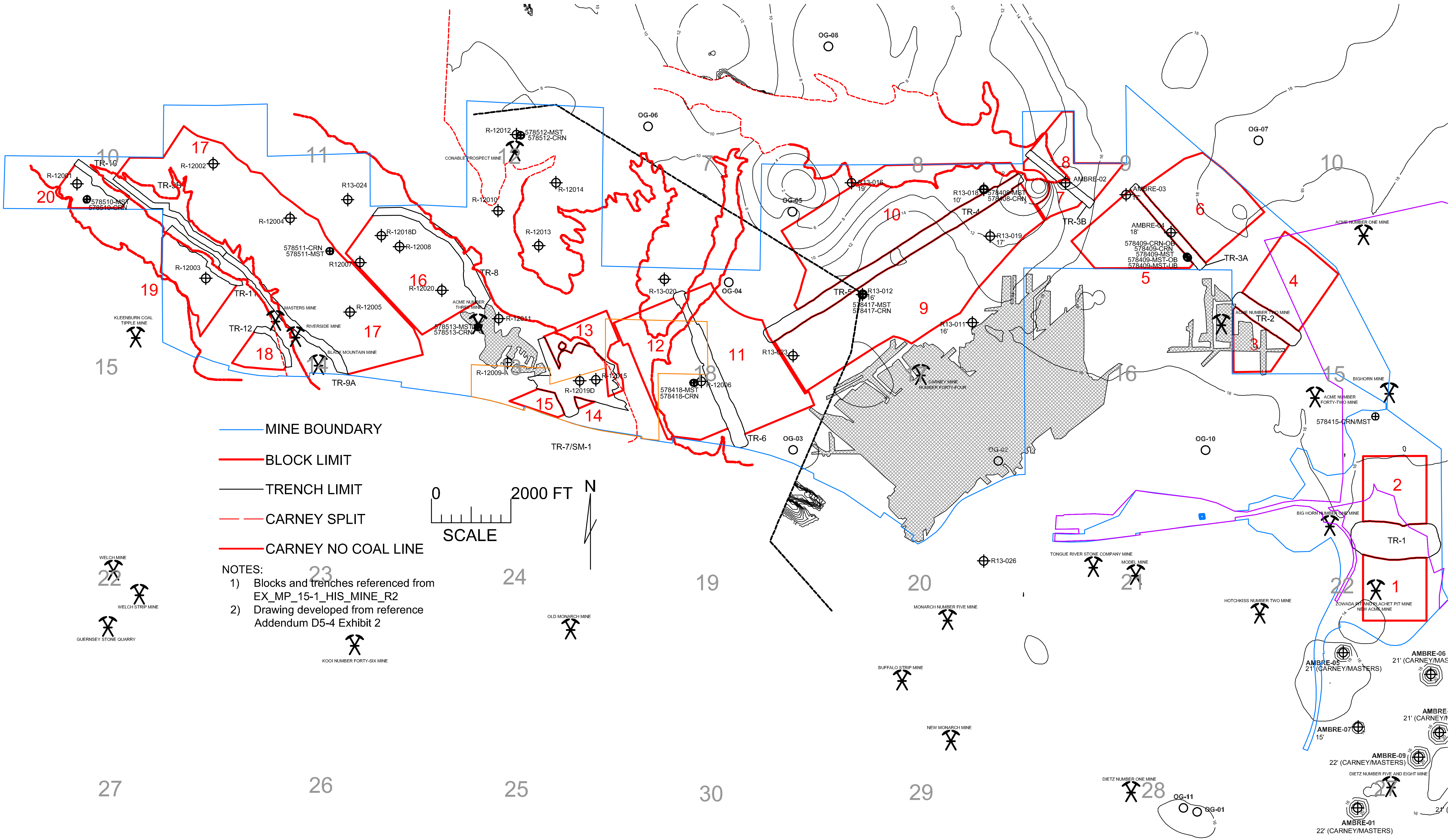

FIGURE 4.6 CARNEY COAL SEAM THICKNESS ISOPACH EAST OF SEAM SPLIT WITH PROPOSED MINE LAYOUT

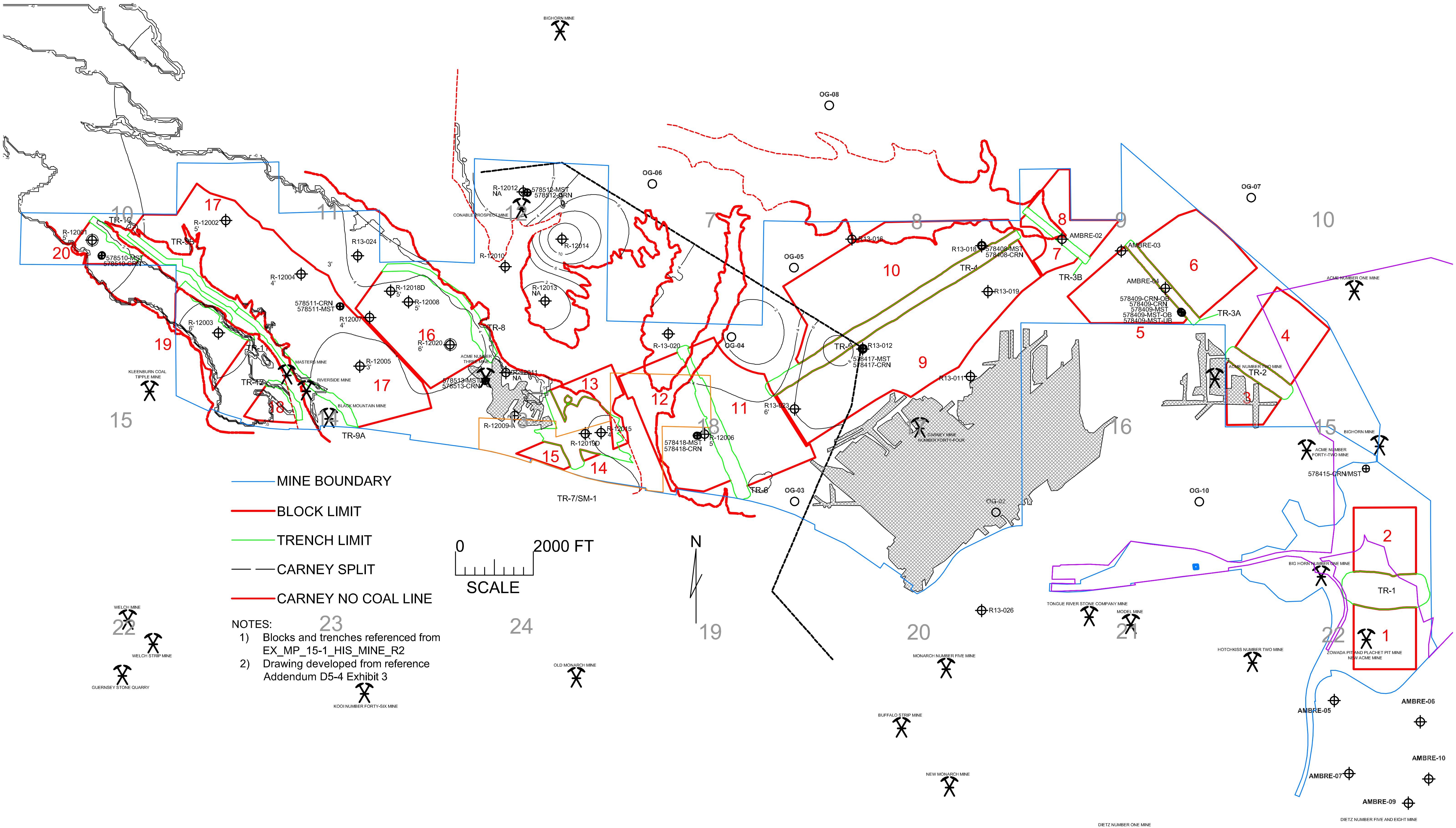

FIGURE 4.7 UPPER CARNEY COAL SEAM THICKNESS ISOPACH MAP WEST OF CARNEY SEAM SPLIT WITH PROPOSED MINE LAYOUT

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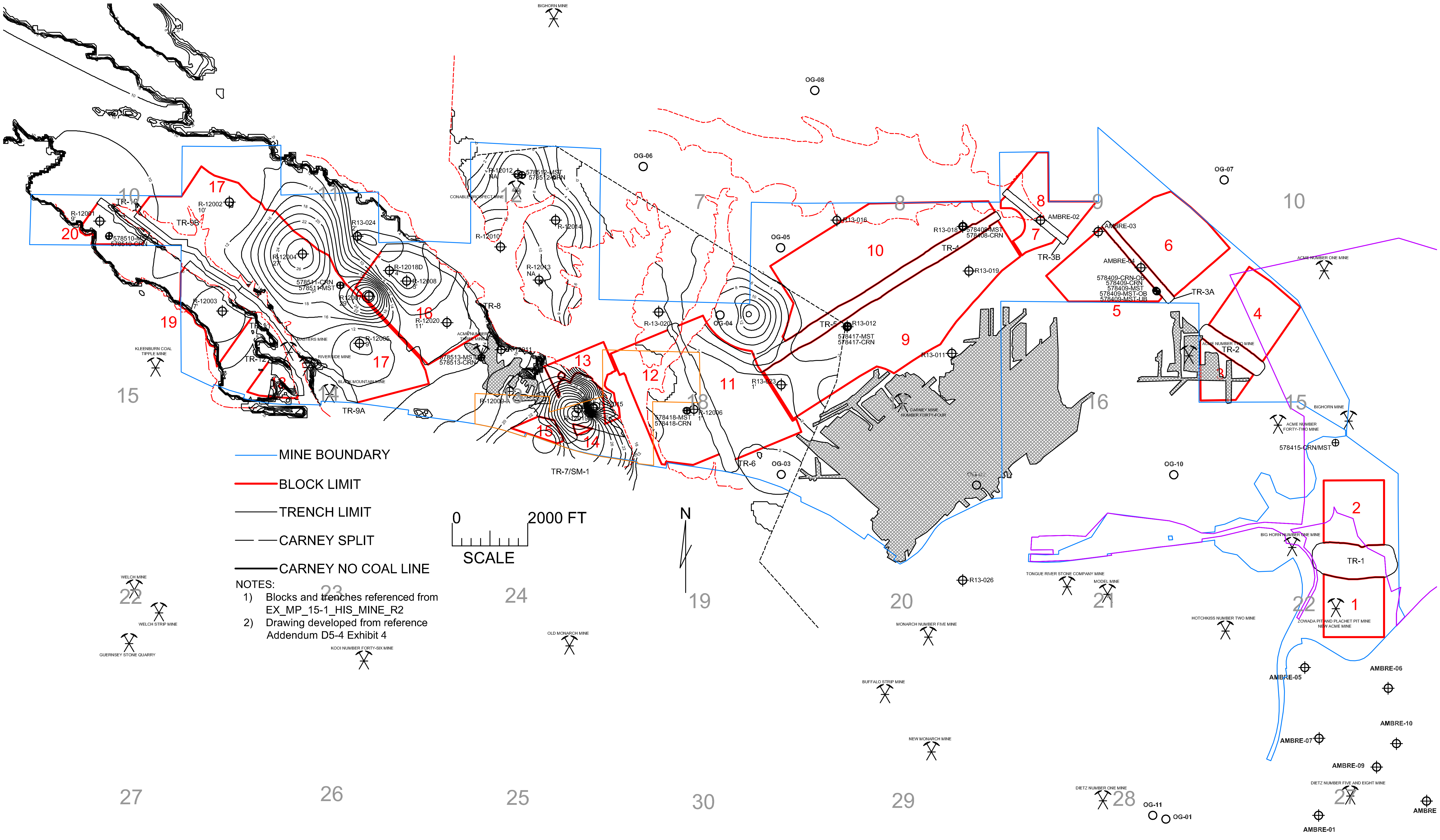

FIGURE 4.8 UPPER AND LOWER CARNEY COAL SEAM INTERBURDEN ISOPACH MAP, WEST OF SEAM SPLIT WITH PROPOSED MINE LAYOUT

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MARINO ENGINEERING ASSOCIATES, INC.©

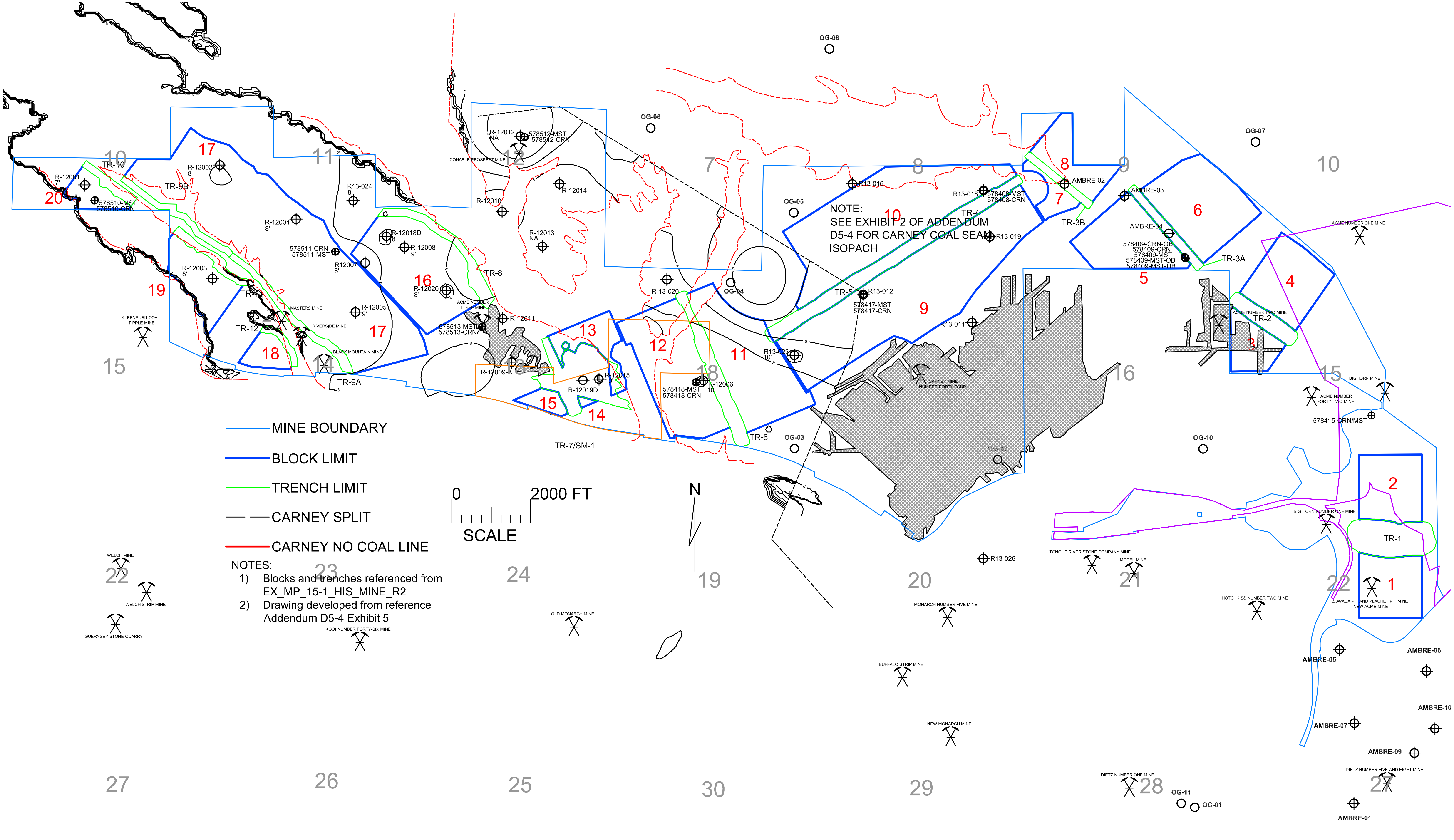

FIGURE 4.9 LOWER CARNEY COAL SEAM THICKNESS ISOPACH MAP, WEST OF SEAM SPLIT WITH PROPOSED MINE LAYOUT

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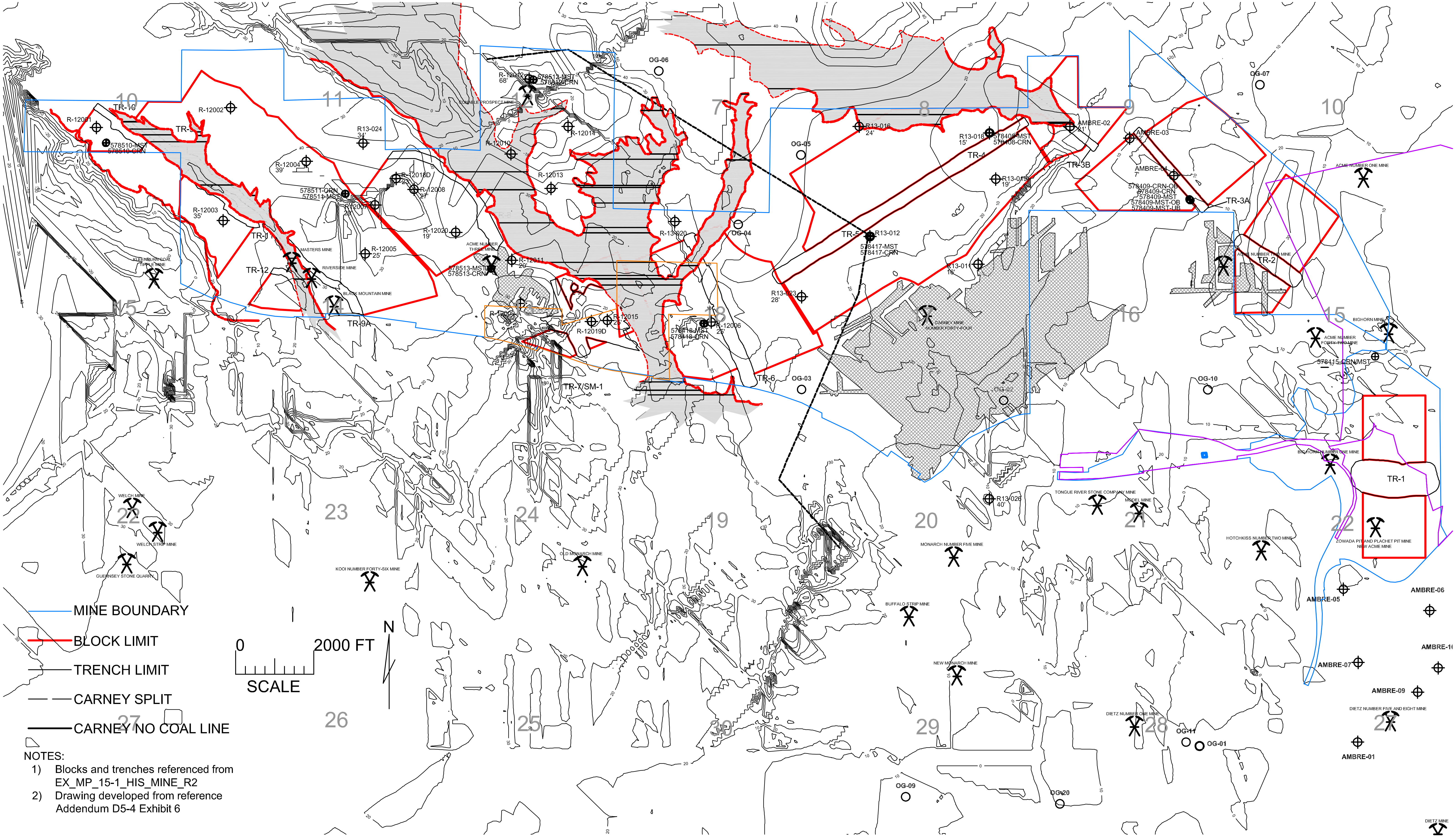

NOTES:

1) Blocks and trenches referenced from EX_MP_15-1_HIS_MINE_R2
2) Drawing developed from reference Addendum D5-4 Exhibit 6

FIGURE 4.10 CARNEY AND MASTERS COAL SEAM INTERBURDEN ISOPACH MAP WITH PROPOSED MINE LAYOUT

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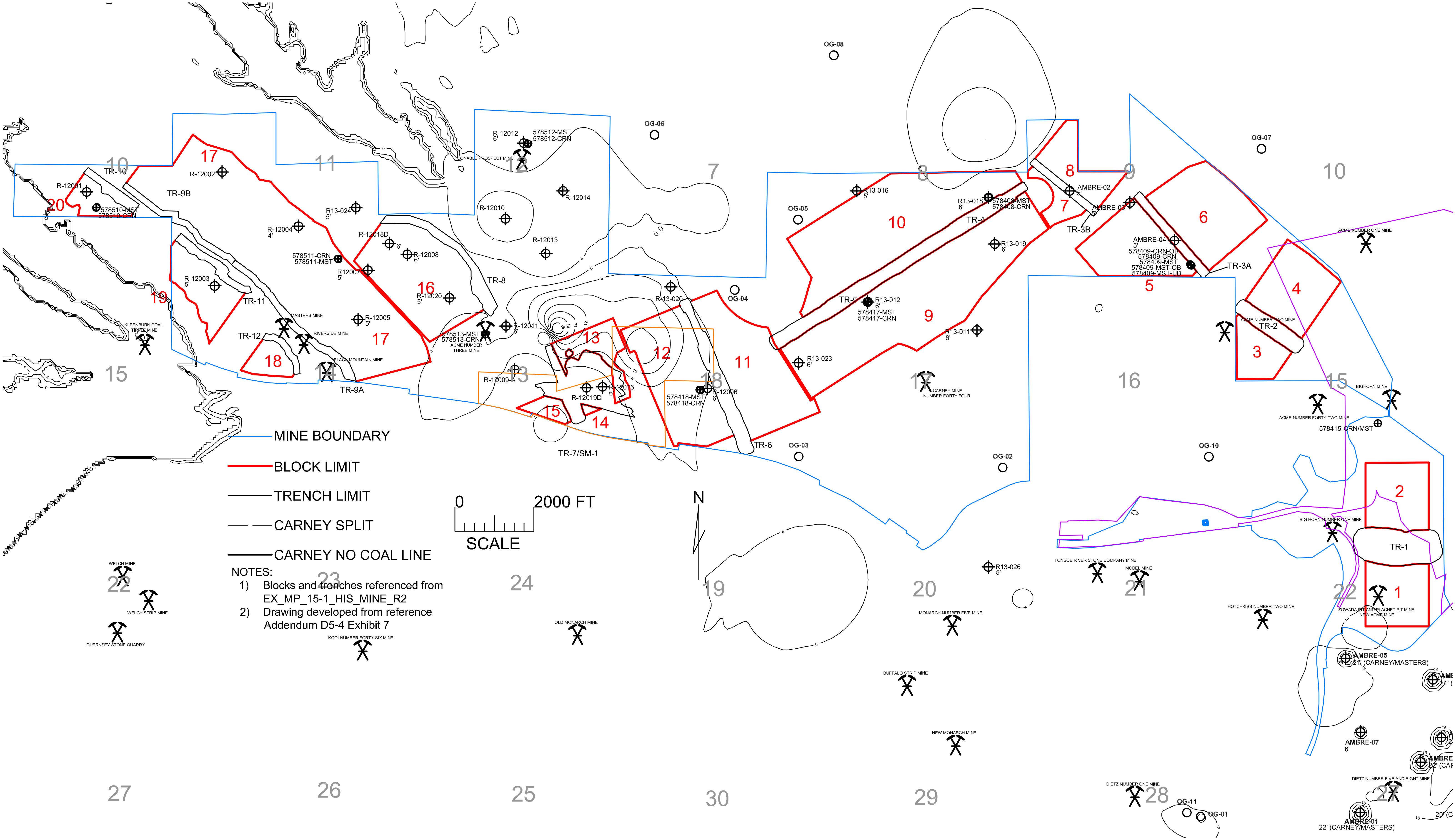

FIGURE 4.11 MASTERS COAL THICKNESS ISOPACH WITH PROPOSED MINE LAYOUT

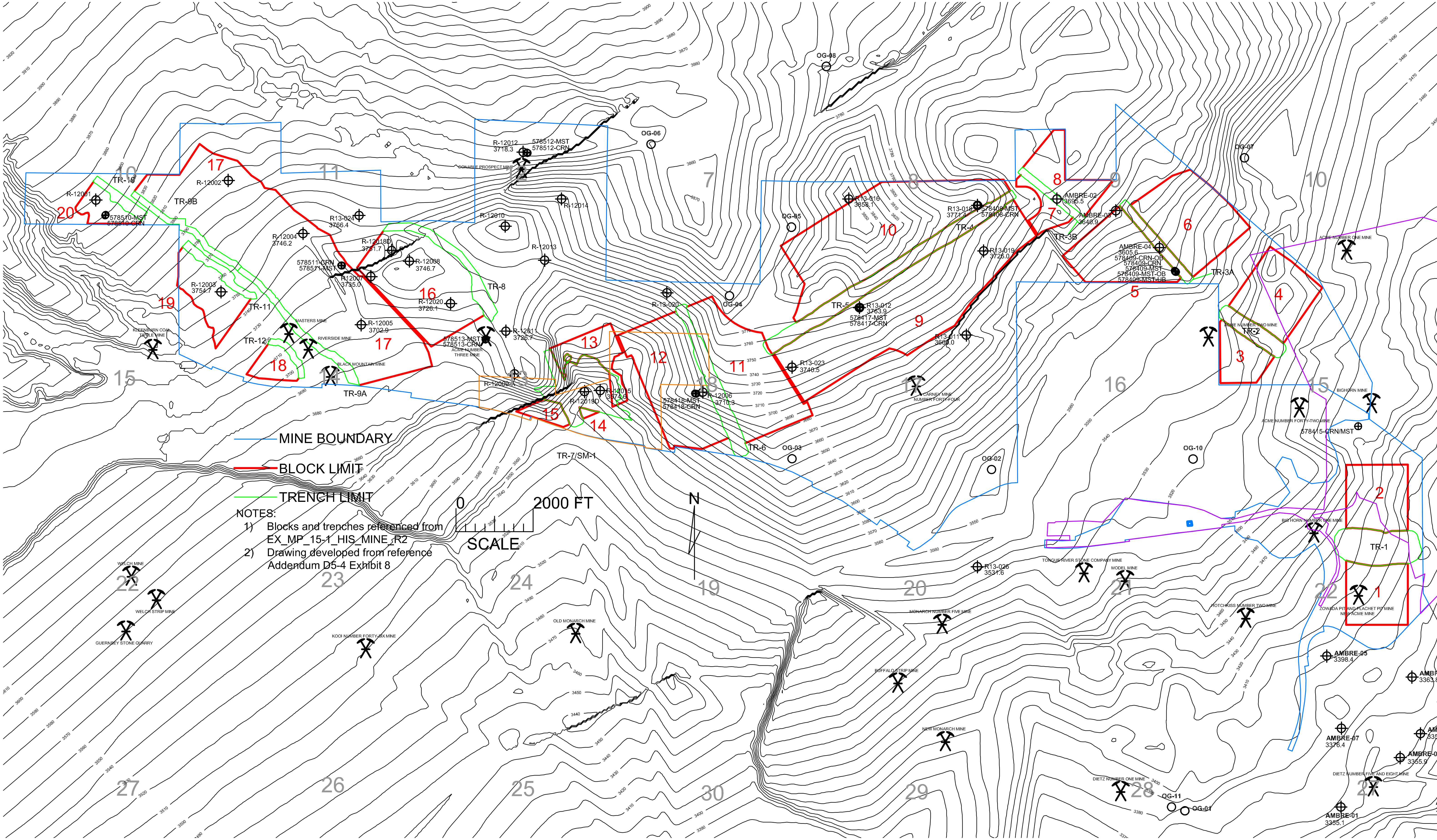

FIGURE 4.12 MASTERS COAL BOTTOM ELEVATION ISOPACH WITH PROPOSED MINE LAYOUT

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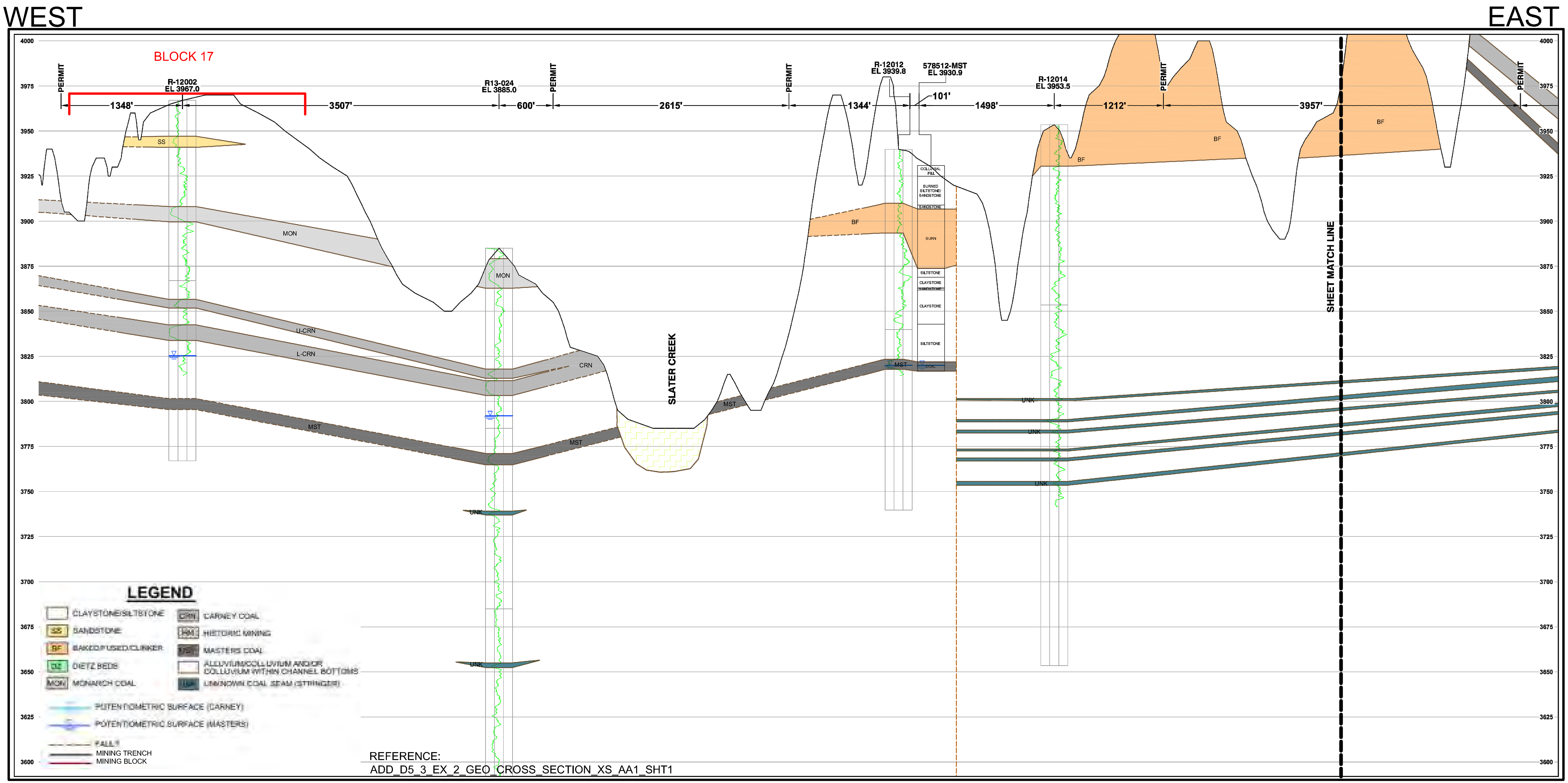

FIGURE 4.13 WEST SECTION OF CROSS-SECTION A-A' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED BROOK MINE

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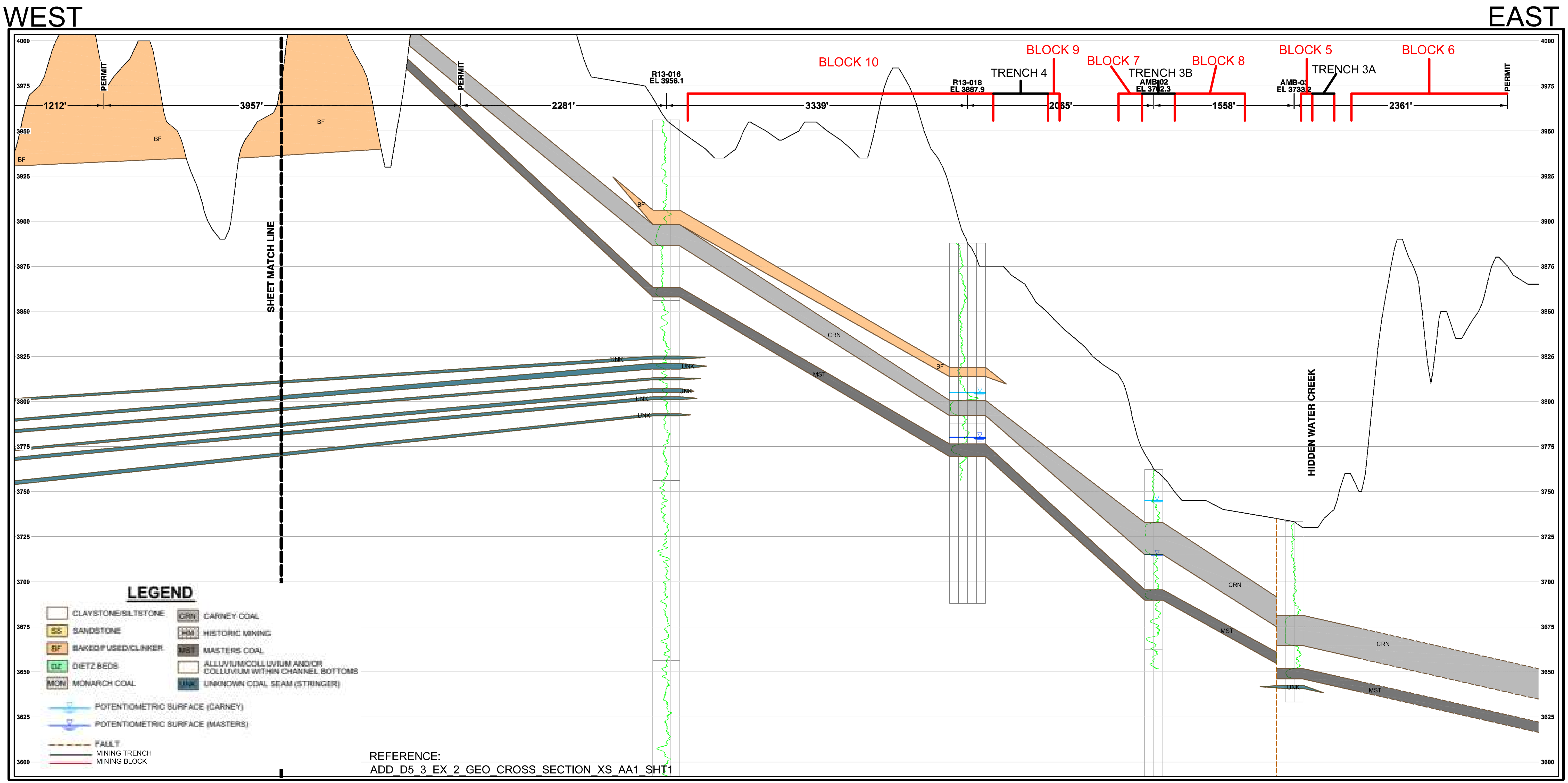

FIGURE 4.14 EAST SECTION OF CROSS-SECTION A-A' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED RAMACO MINE

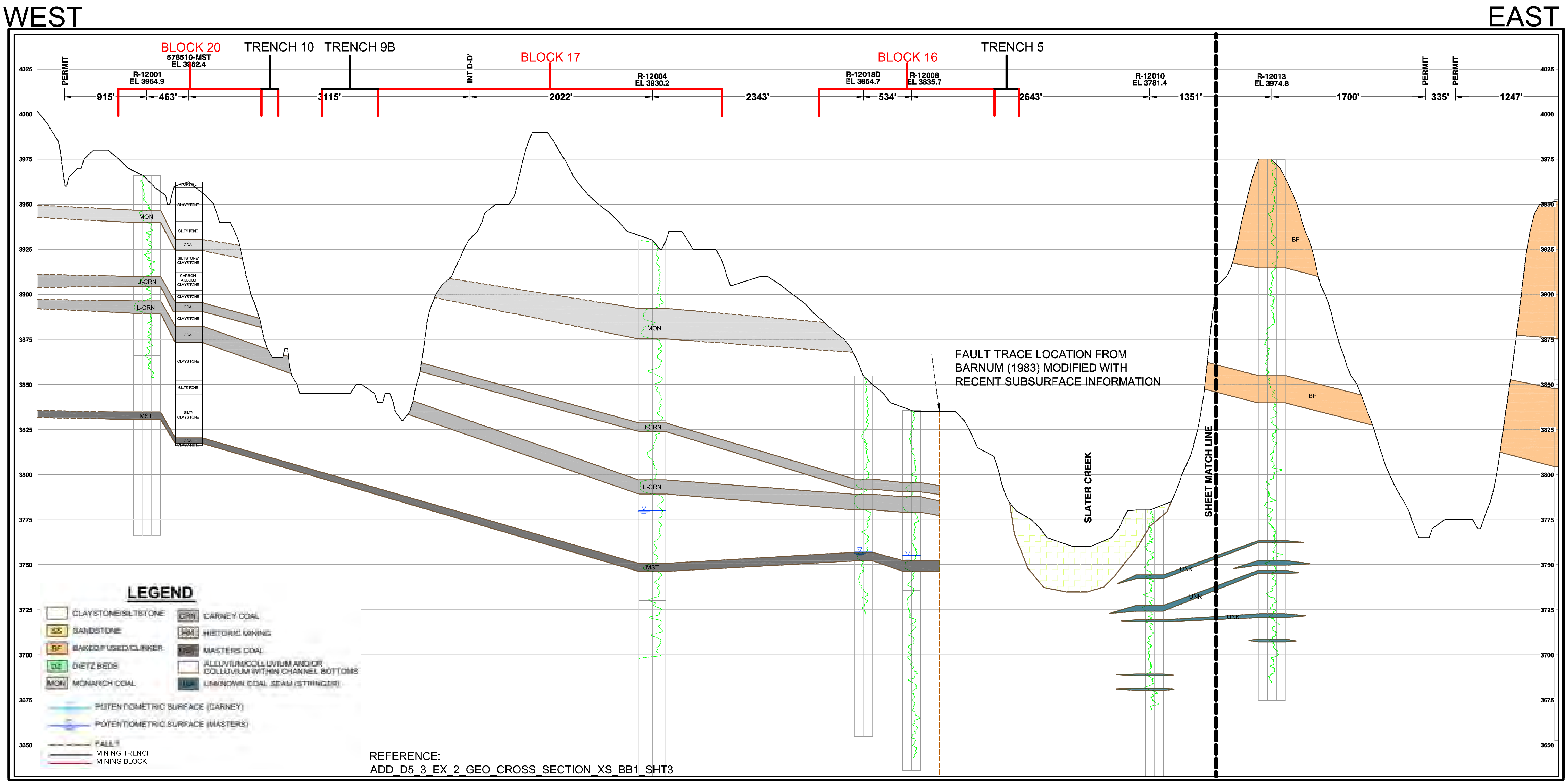

FIGURE 4.15 WEST SECTION OF CROSS-SECTION B-B' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED BROOK MINE

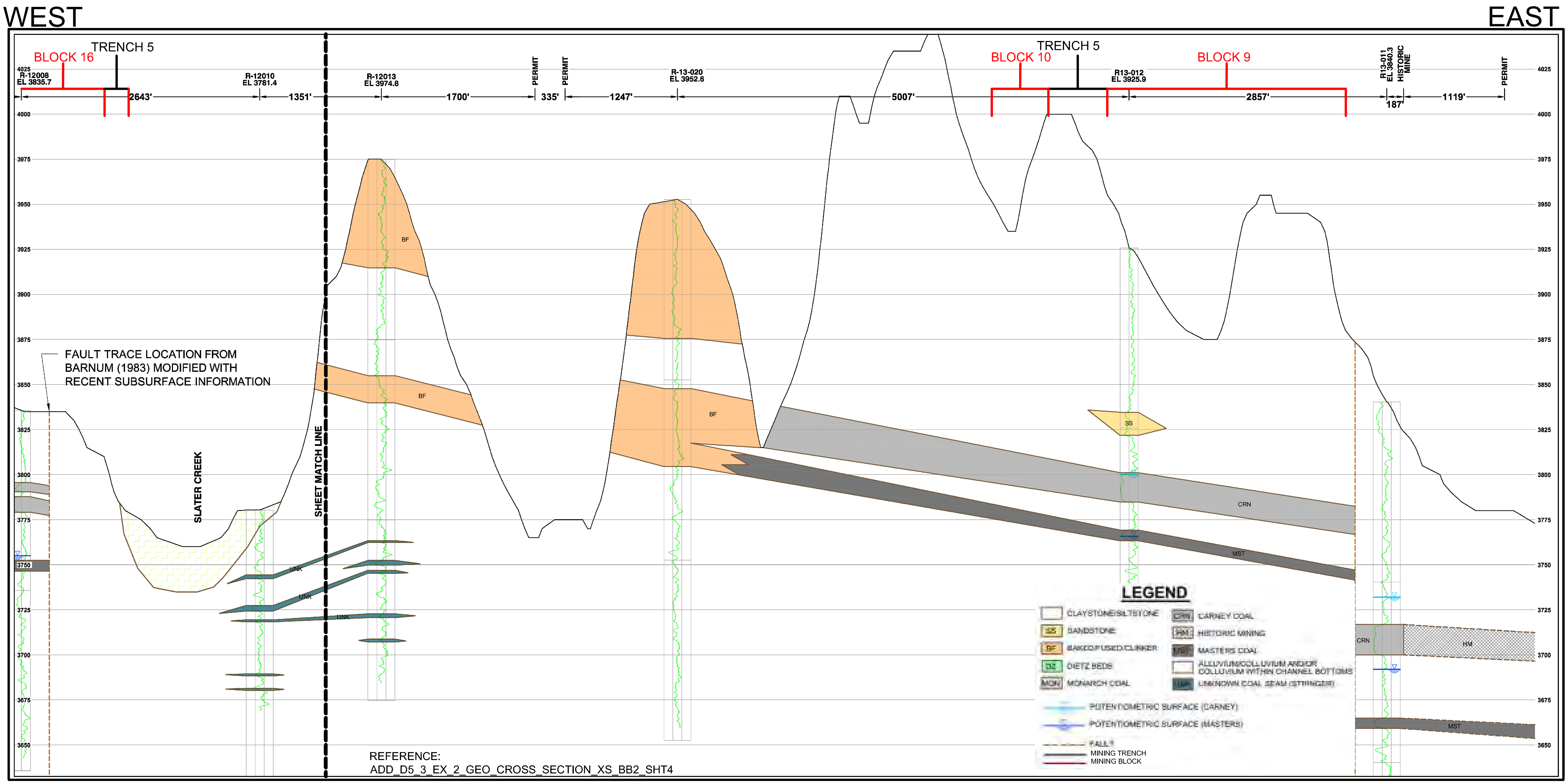

FIGURE 4.16 EAST SECTION OF CROSS-SECTION B-B' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED BROOK MINE

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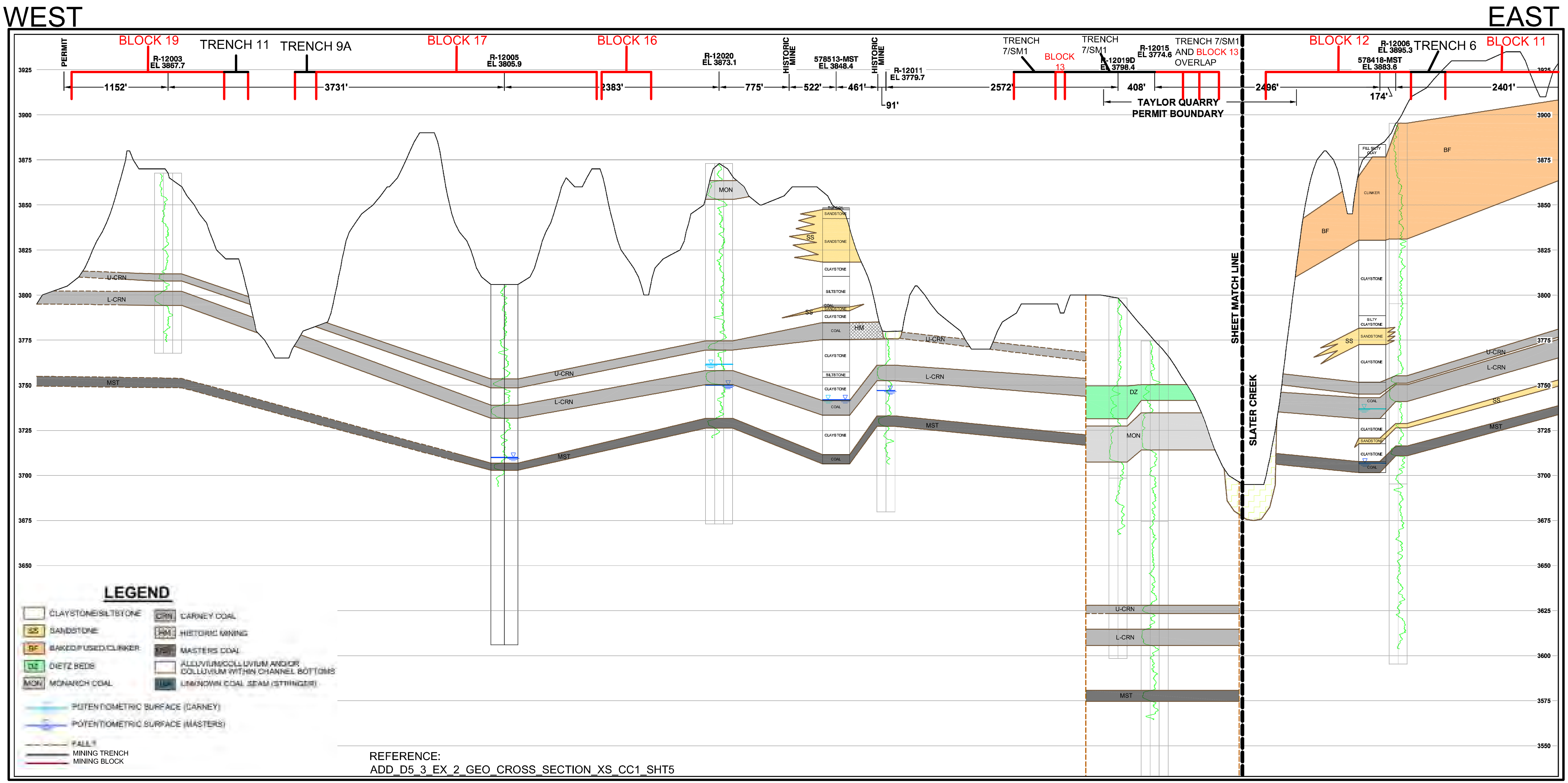

FIGURE 4.17 WEST SECTION OF CROSS-SECTION C-C' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED BROOK MINE

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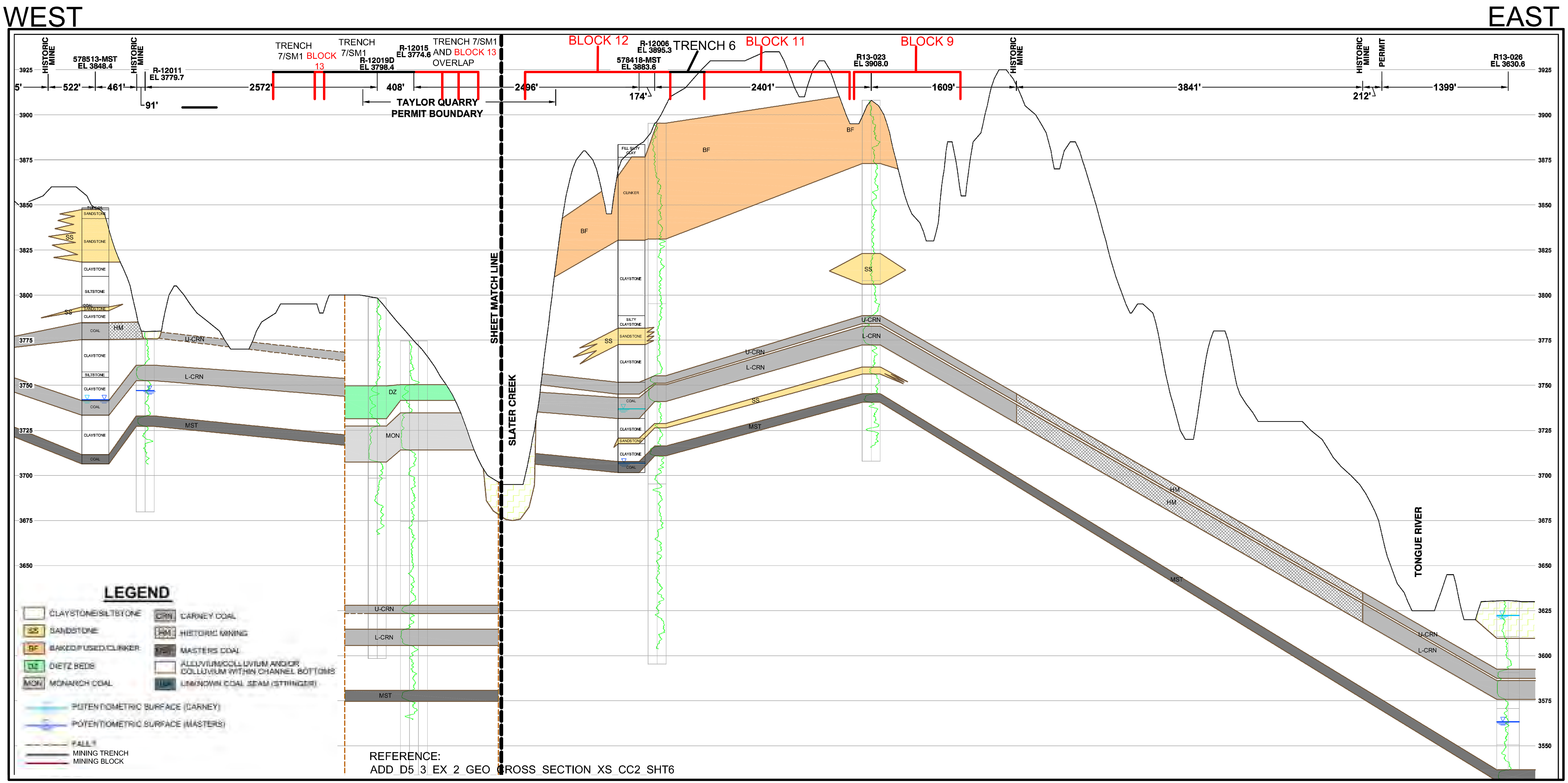

FIGURE 4.18 EAST SECTION OF CROSS-SECTION C-C' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED BROOK MINE

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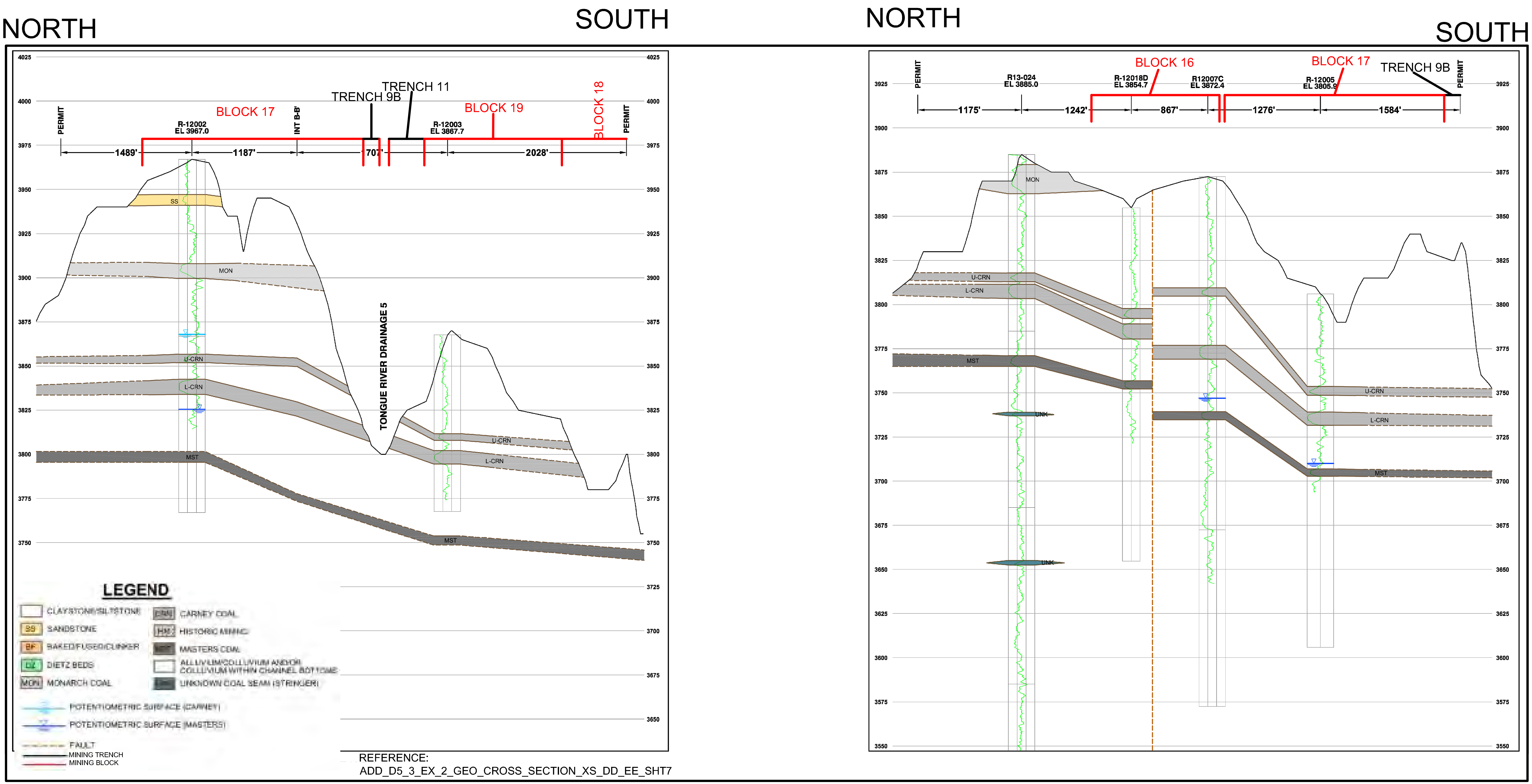

FIGURE 4.19 CROSS-SECTION D-D' AND E-E' SHOWING MINING BLOCK AND TRENCH EXTENTS OF THE PROPOSED BROOK MINE

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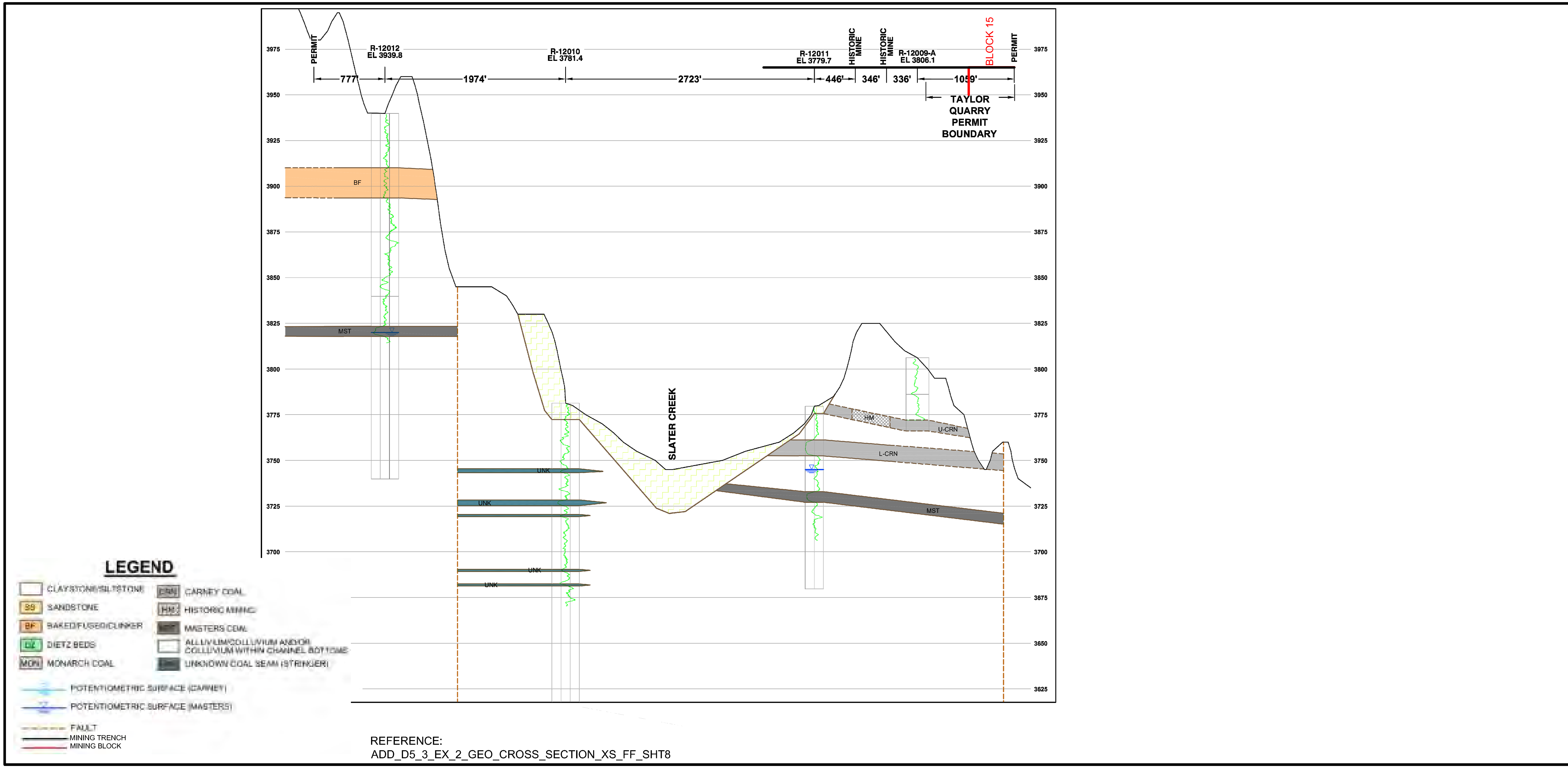
NORTH

SOUTH



REFERENCE:
ADD_D5_3_EX_2_GEO_CROSS_SECTION_XS_FF_SHT8

FIGURE 4.20 CROSS-SECTION F-F' FOR THE PROPOSED BROOK MINE (NO MINING IS PLANNED ALONG THIS CROSS-SECTION)

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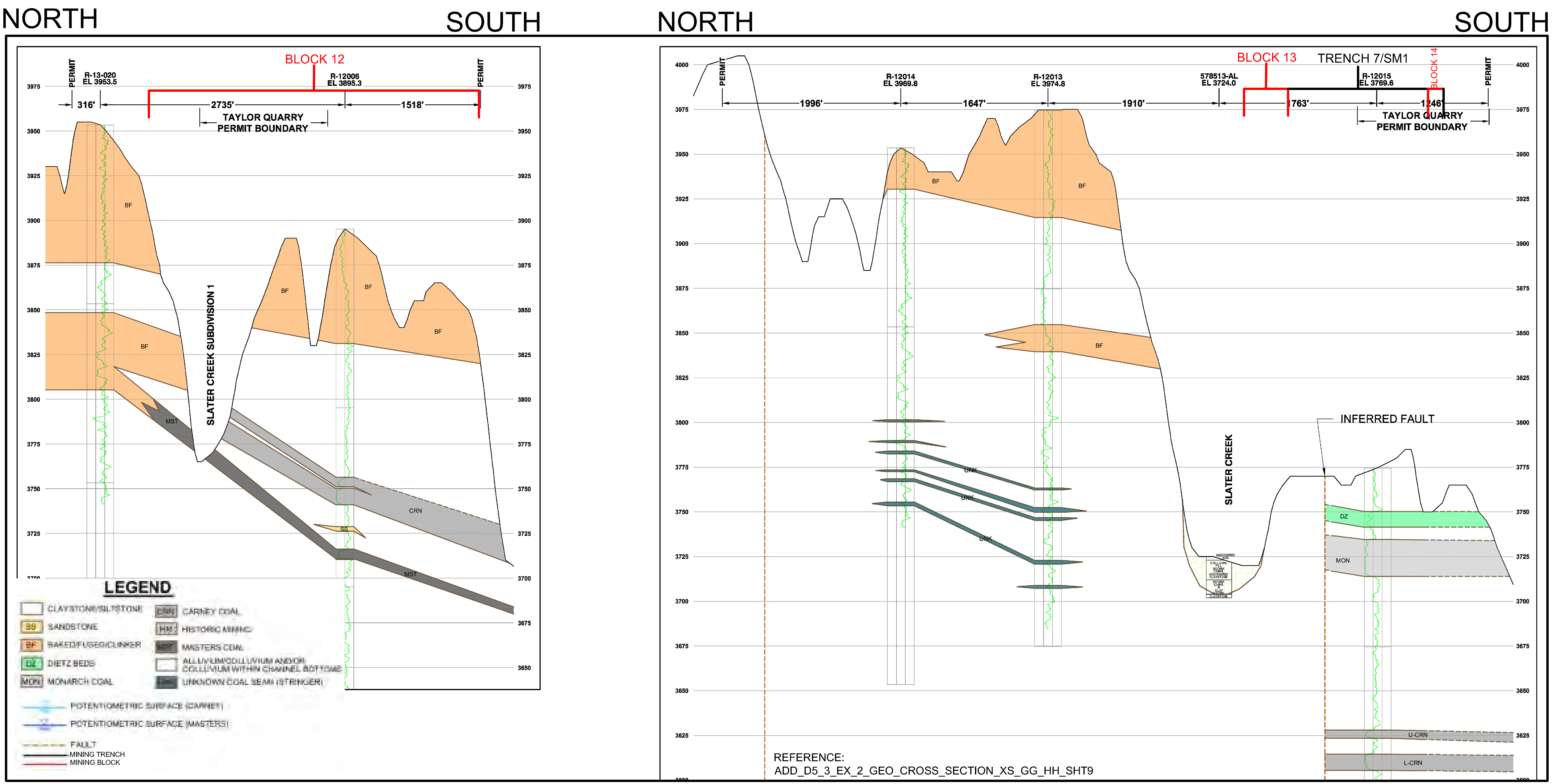

FIGURE 4.21 CROSS-SECTIONS G-G' AND H-H' SHOWING MINING BLOCK AND TRENCH EXTENTS FOR THE PROPOSED BROOK MINE

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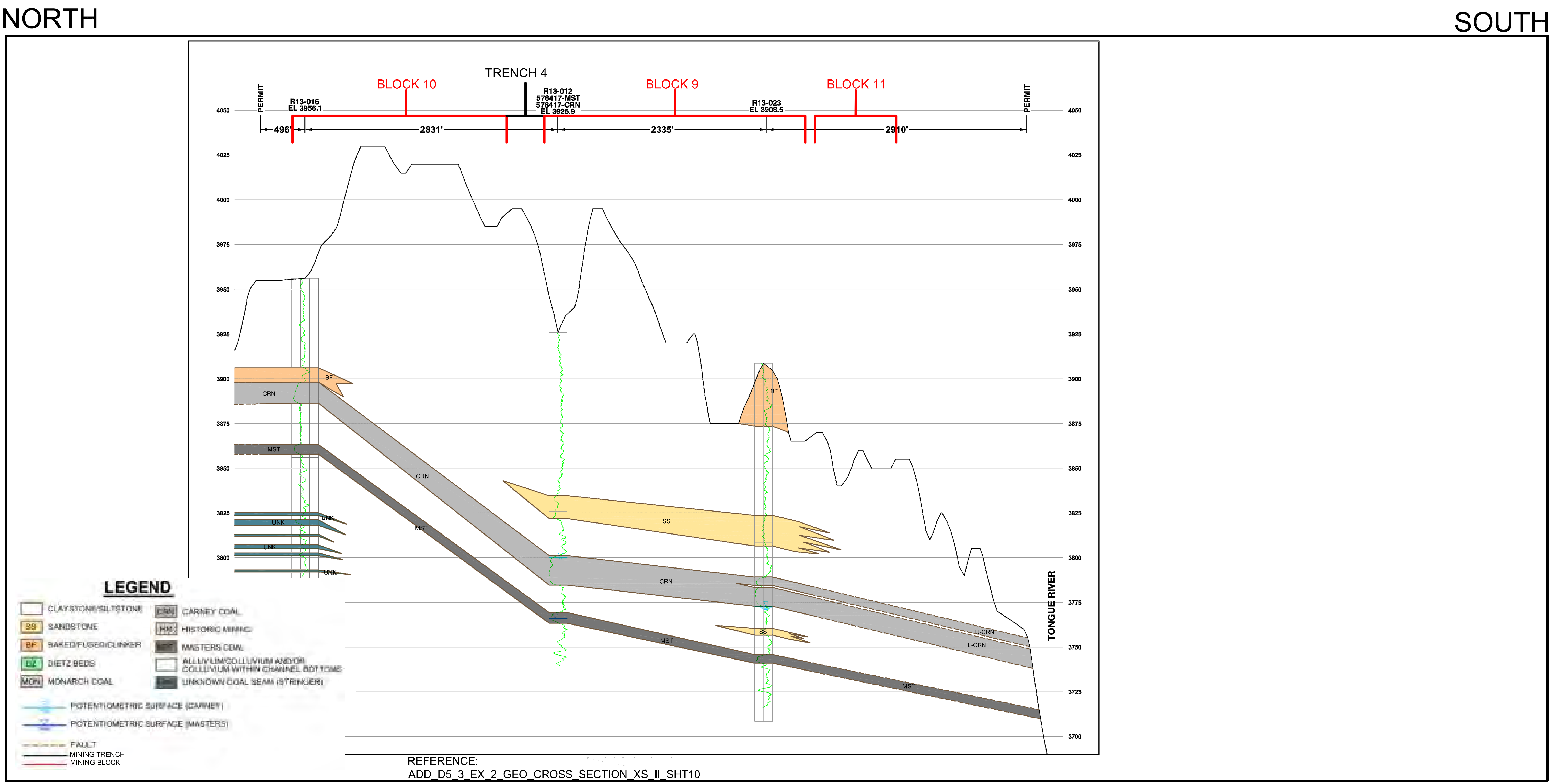

FIGURE 4.22 CROSS-SECTION I-I' SHOWING MINING BLOCK AND TRENCH EXTENTS FOR THE PROPOSED BROOK MINE

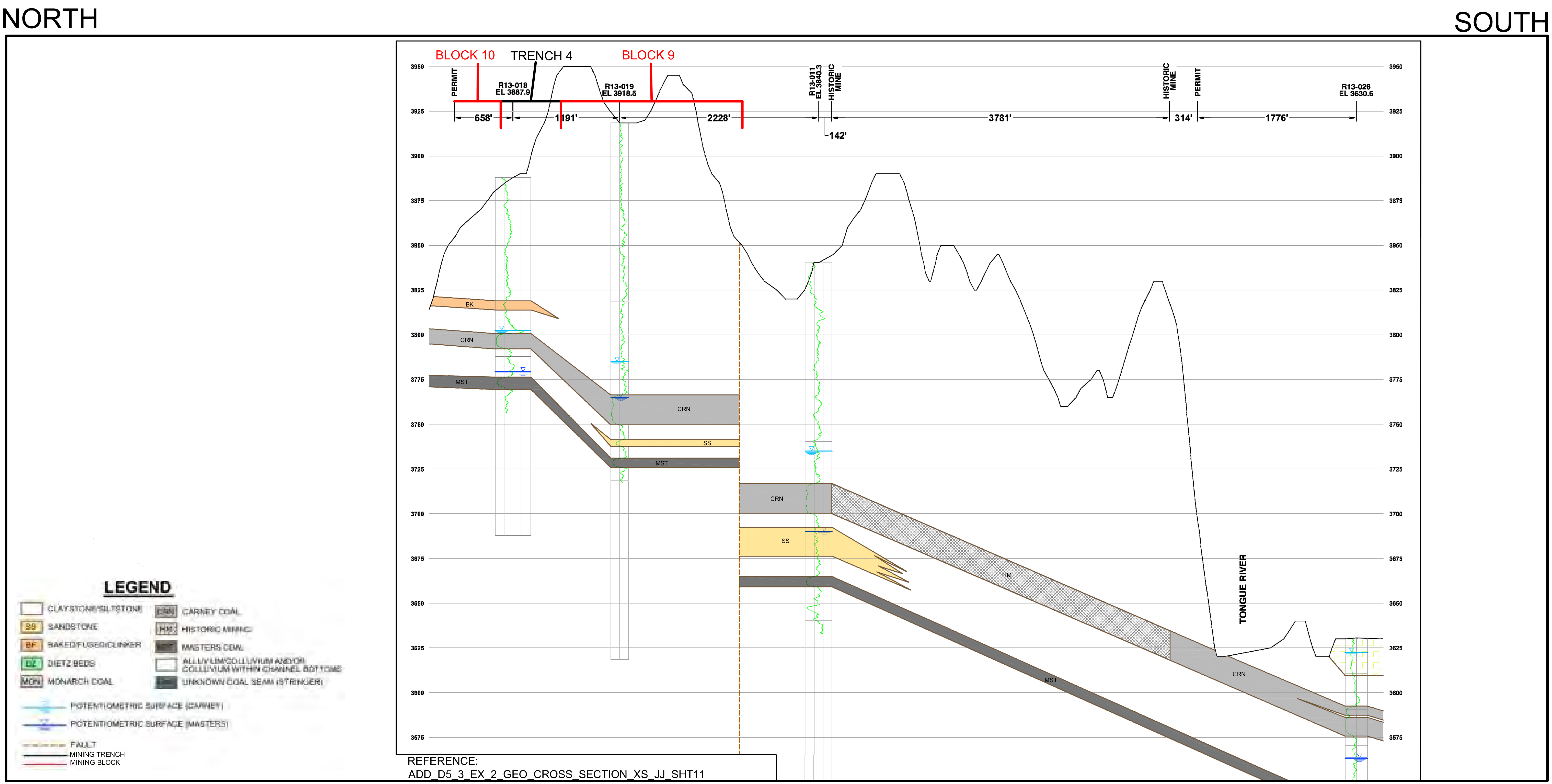

FIGURE 4.23 CROSS-SECTION J-J' SHOWING MINING BLOCK AND TRENCH EXTENTS FOR THE PROPOSED BROOK MINE

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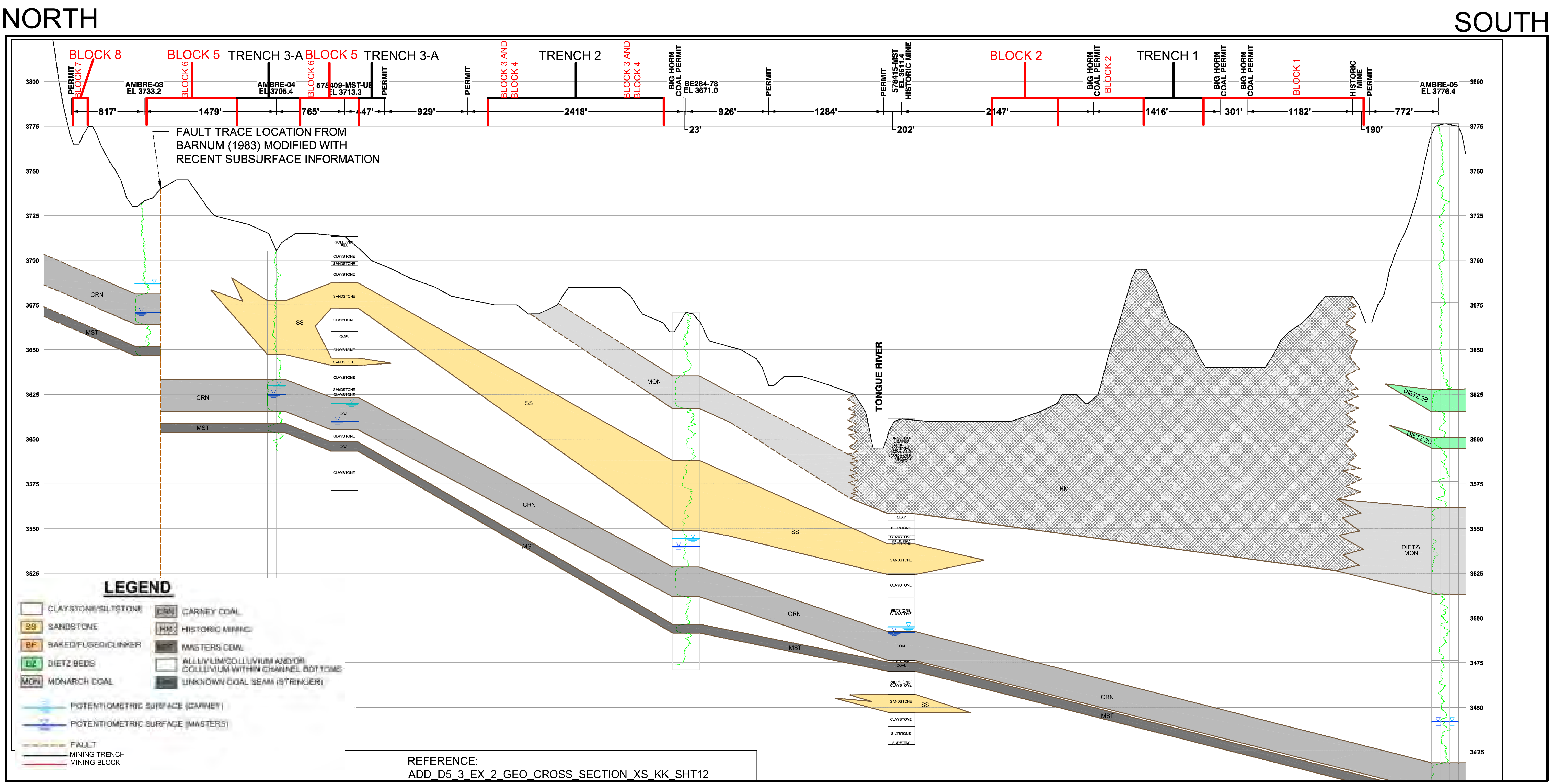

FIGURE 4.24 CROSS-SECTION K-K' SHOWING MINING BLOCK AND TRENCH EXTENTS FOR THE PROPOSED BROOK MINE

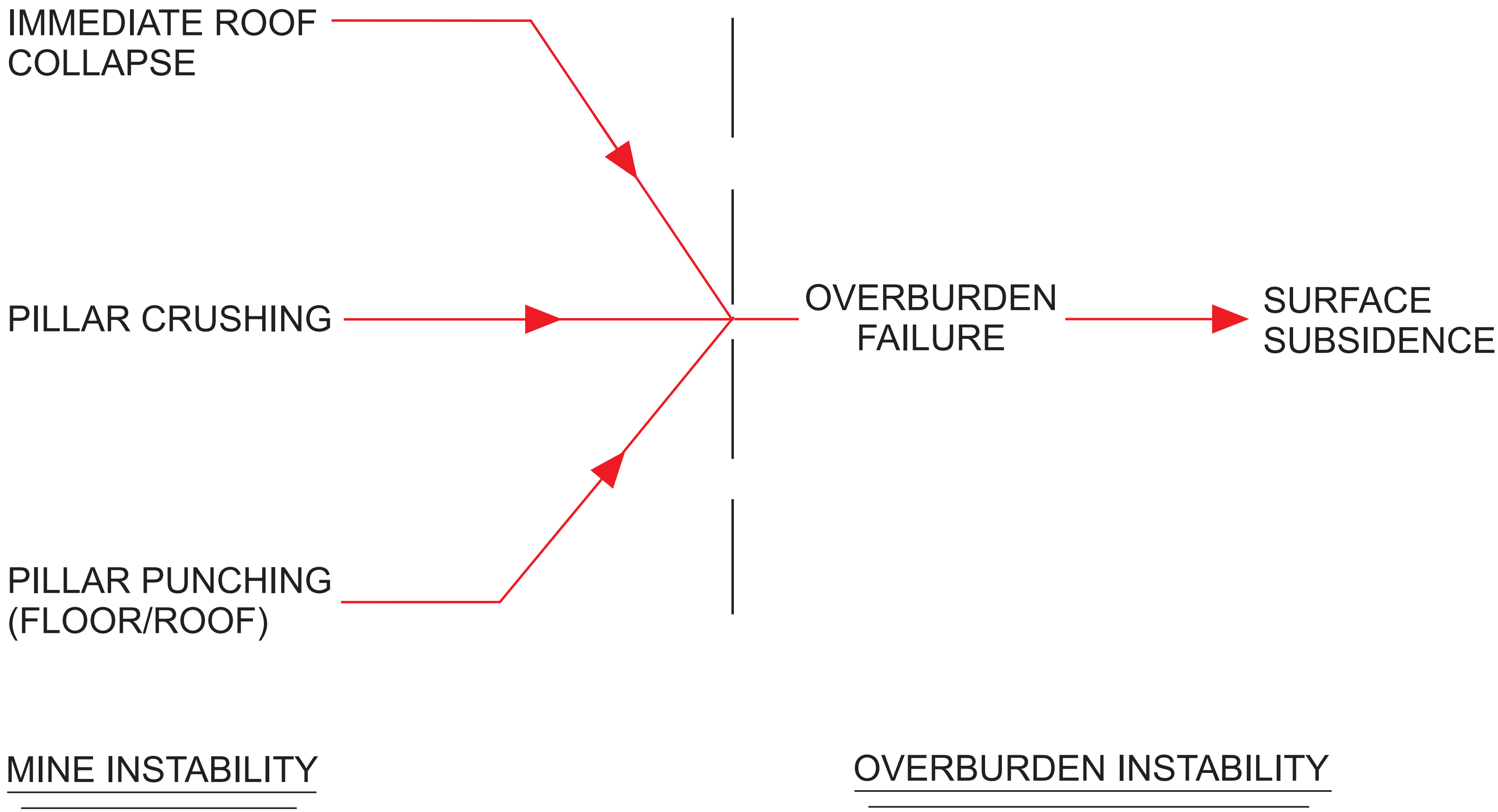

FIGURE 5.1 SUBSIDENCE FAILURE MECHANICS OF ROOM-AND-PILLAR WORKINGS AND THE OVERBURDEN

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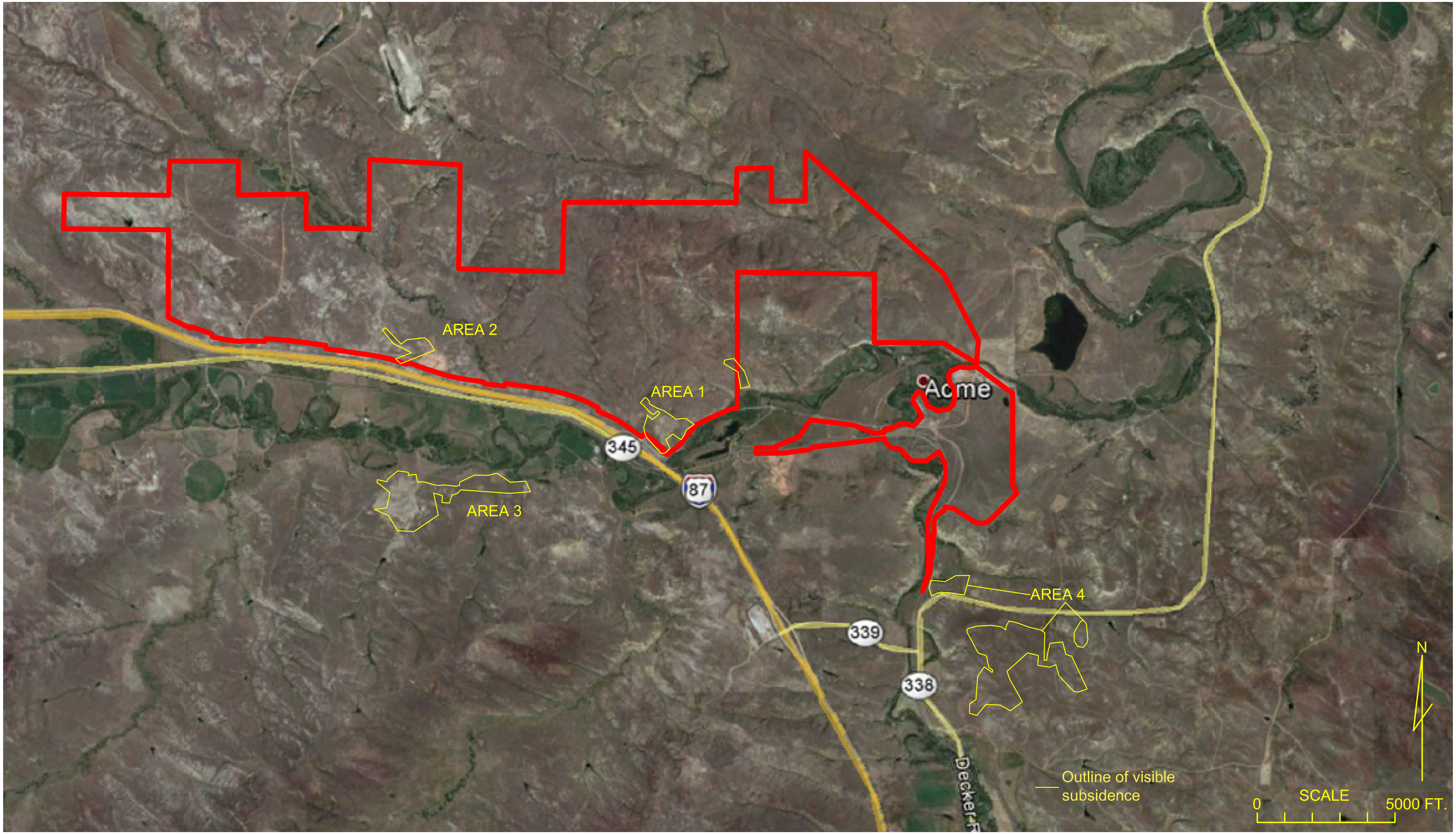

FIGURE 7.1 MINE APPLICATION BOUNDARY AND OUTLINE OF VISIBLE MINE SUBSIDENCE OVER EXISTING UNDERGROUND WORKINGS

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FIGURE 7.2 AREA 1 MINE SUBSIDENCE FROM UNDERGROUND MINING OF THE CARNEY NO. 44 MINE. MINE DEPTH IN NOTED SUBSIDENCE AREA RANGED FROM 50 TO 160 FT. (ADD_D5-4_EX_1_OVB_ISO_R1)

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FIGURE 7.3 AREA 2 MINE SUBSIDENCE FROM UNDERGROUND MINING OF THE OLD ACME NUMBER 3 MINE IN THE UPPER CARNEY SEAM. MINE DEPTH IN THE NOTED SUBSIDENCE AREA IS 60 TO ABOUT 160 FT. (ADD_D5-4_EX_1_OVB_ISO_R1).

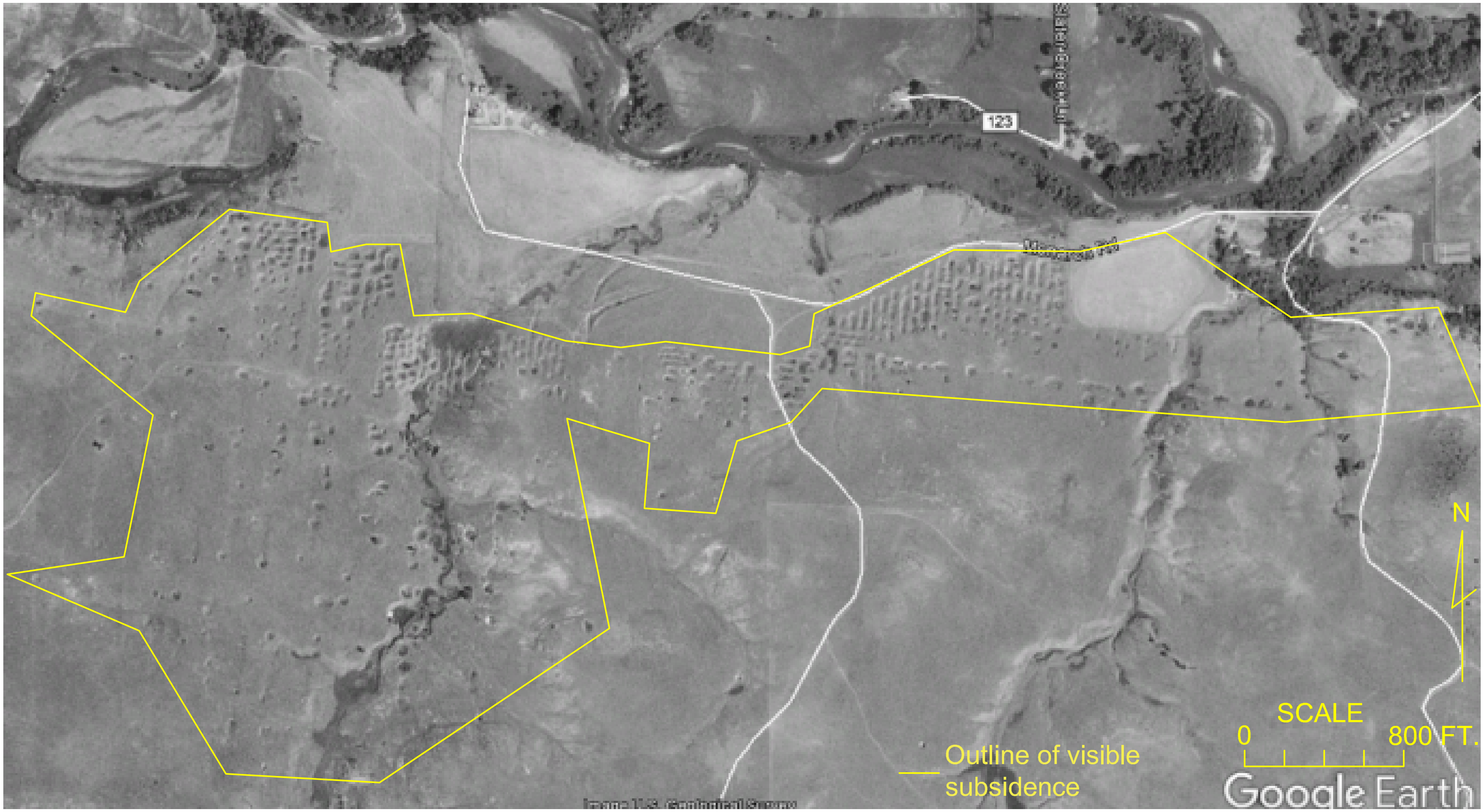

FIGURE 7.4 AREA 3 MINE SUBSIDENCE FROM UNDERGROUND MINING OF THE OLD MONARCH MINE IN THE MONARCH SEAM. MINE DEPTH IS APPROXIMATELY 35-50FT (DUNRUD, C. R., AND OSTERWALD, F.W., 1980).

FIGURE 7.5 AREA 4 MINE SUBSIDENCE FROM UNDERGROUND MINING OF DIETZ MINES NO. 5 TO 8. IN THE DIETZ COAL SEAMS AT ROUGHLY 20 TO 150 FT. BELOW GROUND SURFACE (DUNRUD, C. R., AND OSTERWALD, F.W., 1980).

TABLE 3.1 SUMMARY OF LABORATORY TEST RESULTS ON ROCK MOISTURE, DENSITY, AND BRAZILIAN AND UNIAXIAL COMPRESSION STRENGTHS

SAMPLE	BORING	DEPTH	MOISTURE CONTENT	WET DENSITY	BRAZILIAN TENSILE STRENGTH	UNIAXIAL COMPRESSION STRENGTH	REMARKS
CLAYSTONE	R13-019	150-152 FT.	10.0%	139 pcf	170 psi	--	immediate roof
CARNEY COAL	R13-019	152-153 FT.	25.0%	80.9 pcf	90 psi	1,460 psi	
SILTSTONE WITH CLAY	R13-019	168-169 FT.	8.8%	144.8 pcf	60 psi	500 psi	immediate floor
SILTSTONE	R13-023	110-112 FT.	7.9%	159.4 pcf	440 psi	3,500 psi	likely siltstone, main roof of the Upper Carney
COAL	R13-023	110-112 FT.	20.1%	79.1 pcf	--	--	Coal is not described at this depth - Upper Carney?

References: D5-5-4, D5-5-8, D5-5-10, D5-5-12

TABLE 4.1 DIETZ, MONARCH, CARNEY, AND MASTERS RELATED CONDITIONS PER BLOCK

MINE BLOCK	COAL SEAM	HEIGHT OF SEAM (FT.)	DEPTH OF SEAM TOP (FT.)	ROOF		FLOOR	
				HEIGHT (FT.)	THICKNESS (FT.)	DEPTH (FT.)	THICKNESS (FT.)
1	MONARCH	41	100-1115				
1	CARNEY	14	220-390				
1	MASTERS	5	235-405				
2	MONARCH	MINED OUT	MINED OUT				
2	CARNEY	15-16	120-185				
2	MASTERS	5	145-210				
3	MONARCH	13-15	0-30			29-32	20-32
3	CARNEY	16	80-130	20-35	20-32		
3	MASTERS	5	106-176				
4	MONARCH	13-15	0-30			29-32	20-32
4	CARNEY	16-17	130-370	20-35	20-32		
4	MASTERS	5	156-417				
5	CARNEY	16-17	70-260	3-50WP	0-36		
5	MASTERS	5	93-289				
6	CARNEY	17-18+	70-345	3-50WP	0-36		
6	MASTERS	5	97-373				
7	CARNEY	8 -15	40-105				
7	MASTERS	5	58-160				
8	CARNEY	13-16+	30-225				
8	MASTERS	5	53-256				
9 EAST	CARNEY	6-16	100-220	12-13WP	0-12	7.5-9WP	0-3.5
9 EAST	MASTERS	6	126-256	6.5-7WP	0-3.5		
9 WEST	U CARNEY	4-8	80-220	17.5-18	16.5		
9 WEST	L CARNEY	5-8	85-231			12.5	2.5-4
9 WEST	MASTERS	6	100-259	10-11	2.5-4		
10 EAST	CARNEY	4 - 16	60-240	20WP	0-1.5		
10 EAST	MASTERS	6	74-286				
10 WEST	U CARNEY	4-8	120-200				
10 WEST	L CARNEY	4	125-211				
10 WEST	MASTERS	6	139-245				
11	U CARNEY	3-6	20-160	22-30 WP	0-10		
11	L CARNEY	4-8+	25-172			12	2.5-3.5
11	MASTERS	6	49-210	10-11	2.5-3.5		
12	U CARNEY	4	20-200	8-21WP	0-9		
12	L CARNEY	8-10	25-208			0-16WP	0-3
12	MASTERS	>6-12+	53-248	7.5-10WP	0-3		
13	DIETZ	0-8.5	0-25				
13	MONARCH	0-20	0-40				
13	U CARNEY	4	15-80				
13	L CARNEY	9	21-114				
13	MASTERS	6-14+	50-143				
14	DIETZ	8	0-6				
14	MONARCH	20	16-22				
14	U CARNEY	4	120-150				
14	L CARNEY	9	146-180				
14	MASTERS	5	175-209				

15	U CARNEY	4	100-180				
15	L CARNEY	9	128-214				
15	MASTERS	4	147-253				
16	MONARCH	0-15	0-3				
16	U CARNEY	4-6	40-100				
16	L CARNEY	8-9	47-136				
16	MASTERS	6	65-185				
17	MONARCH	0-17	0-89	30-39WP	0-5.5		
17	U CARNEY	2-5	20-160				
17	L CARNEY	8-9	31-193				
17	MASTERS	4-6	64-237				
18	U CARNEY	0-4	15-45				
18	L CARNEY	2-6	15-61				
18	MASTERS	5	37-97				
19	U CARNEY	4-6	20-60				
19	L CARNEY	2-8	24-76				
19	MASTERS	5	56-124				
20	MONARCH	0-7	0-32				
20	U CARNEY	2-5	20-60				
20	L CARNEY	2-7	22-74				
20	MASTERS	5	54-111				

Notes: WP = where present, as much of the sandstone exists as lenses of varying thicknesses and may not show up in the entire block. Blocks 1, 2, 7, 8, 10 west, 13-16, and 18-20 have no sandstone. In Blocks 3 and 4, the sandstone is present as a thick bed of sandstone. This sandstone thickens towards the south and is thickest south of the blocks and is present as roof of the Carney and floor of the Monarch. In Blocks 5 and 6, the sandstone is thickest in the middle and thins north and south. It is closer to the Carney in the south half of the block and becomes further above the Carney towards the north, where it pinches out to become absent. Between Blocks 5 and 6 in Borehole 578409-MST-UB, there exists 4 small sand intervals above the Carney, the first is 3 ft. above and 3 ft. thick, the second is 18 ft. above and is 3 ft. thick. Between this is an unnamed coal bed which is 5 ft. thick at 32 ft. above the Carney. 50 ft. above the Carney is a 14 ft. thick bed and at 74 ft. above is a 2 ft. thick bed. In Block 9 east of the Carney split, the sandstone exists for both floor and roof material for the Carney and roof material for the Masters. In Block 9 west of the split, sandstone is present in various thicknesses as the roof of the upper Carney, floor of the lower Carney, and roof of the Masters. In Block 10, the sandstone is only present in the southern 35 ft. in Section I-I' and thickens to the south. For Blocks 11 and 12, the sandstone is present in various thicknesses where it exists and is found in the roof of the upper Carney, floor of the lower Carney, and roof of the Masters. In Block 17, the sandstone is only present in northwest corner above the Monarch.

ATTACHMENT C

Room and Pillar Design Recommendations Against Surface Subsidence – Proposed Brook Mine, Sheridan, WY

May 31, 2017

ROOM AND PILLAR DESIGN RECOMMENDATIONS AGAINST SURFACE SUBSIDENCE – PROPOSED BROOK MINE, SHERIDAN, WY

1. ROOF ENTRY FAILURE ANALYSIS

    a. Stoping potential should be evaluated by an accepted equation for the room (entry) and pillar configuration with parameter values representative of the cave-in material.

    b. If stoping height exceeds the ground surface from 1.a., assess whether a rock bed of sufficient strength, thickness, and durability exists to bridge the underlying upward propagation of the cave over the long term. Bed should be at least 2 ft. thick.

    c. If there is no “bridging” overburden rock bed, reduce extraction height and/or width until the potential stoping height is less than the mine depth.

    d. Where there are vertically stacked entries, perform surface subsidence evaluation similar to the above, but consider cumulative extracted height with mine depth of the lowest mined seam where no “bridging” bed is present above in the overburden.

2. PILLAR FAILURE ANALYSIS

    a. Determine vertical pressure on pillars. Account for arching pressures which may be present from varying pillar width and stacking of pillars from multi-seam mining and changing overburden depth.

    b. Determine the maximum extraction height of the coal seam and range in pillar widths for mining under consideration. Appropriately reduce the pillar width which would be affected by the softening/deterioration of any clay parting.

c. Based on testing, determine the appropriate overall large scale cube strength of the seam to be mined. Appropriately reduce the coal strength for any clay partings based on thickness and long term strength of the parting(s).

d. Utilize the Mark-Bieniawski equation to determine the pillar strength assuming the coal strength determined in 2.c.

e. Use appropriate stability factor (or safety factor) for long term stability to determine minimum pillar dimension against failure from outright crushing.

3. ROOF/FLOOR BEARING FAILURE ANALYSIS

a. Delineate roof and floor extending to two times the width of the immediate pillar into durable and non-durable layers using appropriate slake durability testing and classification. Areas of core recovery losses should be considered non-durable rock.

b. Where the rock is appropriately classified as durable to two times the width of the immediate pillar (i.e. potential shearing zone), that roof or floor is considered durable. Where the vast majority of the rocks classify as non-durable over this distance from the pillar, the roof and/or floor is considered non-durable. Where potential shearing zone contains significant amount of non-durable and durable materials, the bearing state is considered mixed.

c. Because the thickness of a specific non-durable zone can play a key role in the bearing strength of the roof or floor, the thickness should be assumed at the value unlikely to be exceeded. A durable rock zone should not be assumed if it is less than 2 ft. in thickness in any location in the area under consideration.

d. For durable roofs or floors:

   i. The average rock strength is determined by an ample number of representative tests which appropriately measure uniaxial compressive strength (averaging assumes reasonable tested strength variation).

   ii. The average rock mass strength is then determined by appropriately considering the degree of fracturing in the rock.

   iii. Utilizing the classical bearing capacity formula for foundations resting on uniform cohesive medium, the ultimate pillar bearing pressure is determined for the roof and floor using the pillar plan dimensions. The cohesion strength of the bearing zone is taken as one half the average rock mass uniaxial compressive strength determined in 3.c.ii.

   iv. The minimum sized pillar is determined for the long term assuming sufficient data has been collected, for the durable roof or floor zone by considering a safety factor of 3 and a pillar pressure based on 2.a.

e. For non-durable roofs or floors:

   i. The strength of the non-durable rock must be considered over the short and long term as these rocks by definition deteriorate over time. In the short term, the average, representative compressive strength of the fresh rock at its natural moisture should be determined from an ample number of tests throughout the potential shearing zone. For the long term strength, the non-durable rock will revert to a soil-like consistency and thus drained friction and cohesion values representative of this state should be established from adequate testing of the specific stratum under consideration.

   ii. For short term roof or floor bearing, these fresh non-durable rocks (unexposed to groundwater) should behave more as a rock and consequently rock fracturing should be appropriately accounted for in determining the rock mass strength. Obviously, in the long term, the effect of rock fracturing can be discounted as the non-durable rock will be soil-like.

iii. For a reasonably uniform non-durable in the potential shearing zone, the classical bearing capacity formula for foundations resting on a uniform medium can be used to determine the ultimate bearing pressure for the roof and floor and the plan pillar dimensions. The cohesion strength of the bearing zone is taken as one-half the average rock mass strength determined in 3.e.ii. In the long term, the same equation can be used to determine the ultimate bearing capacity.

   Where two distinct non-durable zones with different strengths are present, utilize the appropriate foundation bearing relationship for this condition in either the short or long term.

iv. The minimum sized pillars are determined, assuming sufficient data has been collected, by considering a safety factor of 3 for the roof, 3 in the short term, and 2 in the long term for the floor.

f. For durable rock over non-durable rock, or non-durable over durable rock:

   i. Representative strengths of distinct durable and non-durable zones within the potential shearing zone are determined as respectively given above.

   ii. The ultimate bearing roof or floor capacity should be determined by appropriate relationship which represents the non-durable and durable conditions present.

   iii. Both short term and long term safety factors should be determined to establish the minimum acceptable pillar width. For roof condition, the short and long term safety factor should be 3. For the floor, a factor of safety of 2.0 should be used for all cases.

4. The above recommendations assume that no significant engineering geological features are present, and that a sufficient number of borings were performed, to where it is unlikely that more adverse ground conditions remain unknown.

April 16, 2020

MEMORANDUM

TO: Shannon Anderson
Powder River Basin Resources Council
Sheridan, WY

FROM: Mike Wireman
Granite Ridge Groundwater
Boulder, CO

SUBJECT: Review of: Ramaco Carbon revised permit application (submitted in March 2020) for the proposed Brook Mine, Sheridan County, WY

BACKGROUND

On September 28, 2017 the Wyoming Environmental Quality Council (EQC) issued Findings of Fact, Conclusions of Law, and Order related to Brook Mining Company, LLC's (Brook) application for a permit (submitted in October 2014) to mine coal on lands it owns and controls in Sheridan County, Wyoming. The EQC ordered that Brook's permit not be approved. The EQC decision was based primarily on the inadequate characterization of the hydrogeology, surface water hydrology and potential for subsidence within the proposed mine permit area and adjacent areas. The lack of an appropriate baseline hydrologic characterization precluded the completion of a Cumulative Hydrologic Impact Assessment (CHIA) as required pursuant to Wyoming Statute W.S. § 35-11-406(n). Without a rigorous baseline characterization assessment, including a CHIA, it is not possible to develop and implement an adequate plan to minimize disturbances to the prevailing hydrologic balance at the mine site and in associated offsite areas or to determine if the proposed mining operation has been designed to prevent material damage to the hydrologic balance outside the permit area and will not materially damage the quality and quality of water in the surface water and groundwater systems that supply alluvial valley floors (AVF) as required pursuant to Wyoming Statutes W.S. § 35-11-406(b) and WS 35-11 406 (n).

After the September 2017 EQC decision Brook worked with the Wyoming Department of Environmental Quality (WDEQ) - Land Quality Division (LQD) to address the 14 relevant Orders related to the inadequate hydrologic characterization including the need to better characterize the : (a) hydrology in the vicinity of TR-1, (b) the hydrology of the coal seams (including overburden and underburden), (c) the hydrology of the Tongue river alluvial aquifer, and the Slater Creek alluvium and (d) flow in the Tongue River and Goose Creek. As part of this effort, Brook collected a minimal amount of new field data in 2018. On October 19, 2018 WWC Engineering, on behalf of Ramaco Carbon (owner of Brook mine) submitted a revised permit application with some significant changes to the original mine plan:

1. there will be no mining south of the Tongue River in the TR-1 area;
2. the Masters coal seam will not be mined -only the Carney seam will be mined;
3. mining will start in the Taylor Quarry area -for first 5 years;
4. there are declared AVFs on Slater Creek and the north side of the Tongue River within the permit boundary. These were determined pursuant to State Decision Documents for permits 213-T1 and 497-T1.

The LQD reviewed and provided comments on the October 2018 revised permit application and on September 20, 2019 Brook submitted a second revised permit application. In February 2020, after further review and comment, LQD notified Ramaco Carbon that Brook Mine's permit application has been deemed technically complete under applicable Wyoming statutes. The LQD also released draft Comprehensive Hydrologic Impact Assessment (CHIA) in February 2020. On Nov. 19, 2019, Brook Mine submits application for permit to mine (WDEQ - LQD Form 1).

The revised permit application includes major revisions to Volume 5 (Hydrology). Volume 11 (Mine Plan) and Volume 12 (Reclamation). My review of the revised permit application is focused on Appendix D6 (Hydrology), Appendix D11 (Alluvial Valley Floors), Addendum MP-3 (Groundwater Model) and operational and post-closure water resource monitoring.

GENERAL COMMENTS

1. The revised mine plan excludes the TR-1 area in the vicinity of the BHC pits 1 and 2 and excludes the Masters coal seam from the planned mining. These changes will result in significantly reduced coal production and a different footprint than the original mine plan. The area where Brook proposes to mine the Carney seam includes more than 4000 acres immediately north of the Tongue River. The revised mine plan includes both highwall mining and open pit mining. Slater Creek, an intermittent stream and Hidden Water Creek, an ephemeral stream, flow from NW to SE across the permit area.

2. Surface water and groundwater use is significant in the area close to the permit area. There are 45 reservoir rights, 47 ditch diversion rights and 14 unpermitted reservoirs. The diversions are primarily (70%) used for irrigation, including irrigation of Alluvial Valley Floors. There are 480 groundwater wells within the vicinity of the mine permit area. These wells are producing from the Ft. Union Formation and used primarily for domestic and stock watering use.

3. Much of the permit application contains older (2014-2015) and superceded data and information and was written when the mine plan was substantially different (see above) and

does not accurately reflect the current mine plan. This is confusing and makes review of the document more difficult.

4. In October 23, 2014 Brook submitted Application for License to Mine (DEQ - LQD Form 3). Is this License still valid?

5. In 2016 Brook prepared an estimate of the surface damage bond for BH coal surface ownership. Estimate was approx. $1900.00 based on potential forage loss. Bond is only for first year? Is this still in place?

MAJOR CONCERNS

1. The baseline hydrology of the Tongue River alluvium / Tongue River system is still not characterized adequately. The new water level and water quality data collected in 2018 is very limited and insufficient to adequately characterize baseline hydrologic conditions and assess potential impacts to alluvial valley floors from the proposed mining. The characterization of recharge, flow and discharge from the Tongue River member of the Ft. Union -which includes the Carney and Masters coal seams is inadequate. This is due to having too little data and the complexity of groundwater flow in the Tongue River member of the Ft. Union Fm. Brook is relying primarily on old data to characterize current baseline conditions. The revised permit includes a discussion of the "groundwater material" in the 2002 BHC permit 213. This data is very old and focused only on the area around the open pits on the BHC mine permit area – not useful for characterizing current hydrogeologic conditions in the Tongue River member including the coal seams (Carney) and interbedded lithologies (SS, Siltstone, clay).

2. The groundwater model was developed specifically to look at the radial extent of drawdown in the coal aquifers associated with mine related dewatering of the coal seams and the potential decline of water levels in nearby domestic /stock wells. The modeling effort did not assess potential impacts to the Tongue River alluvial aquifer (and AVFs) from long term changes to the groundwater flow system (recharge, flow and discharge) in the Tongue River member. The groundwater model results have high uncertainty due to the sparse data sets and inability to simulate variably saturation conditions and multiple flow systems in the Tongue River member of the Ft. Union Fm. Predictions of drawdowns at domestic well locations have very large uncertainty. Significant problems with the modeling efforts included difficulties with calibration, convergence and inability to use applicable sub-package.

3. The operational and post-mining water resource monitoring programs are poorly described in the permit application. There is no sampling and analysis plan provided for either monitoring program. There is no surface water monitoring location on the Tongue River located above the mine permit boundary nor is there a monitoring well in the Tongue River alluvium above the mine permit boundary. The proposed post-mining monitoring frequency (annually) is not appropriate for establishing post -mining water level and water quality trends. It is unclear how many and which monitoring locations are still accessible and useable. There is no information regarding the role of the WDEQ - LQD with respect to approval of the proposed monitoring program and no discussion the criteria that will be used to reduce or eliminate post-closure monitoring and release Brook's bond.

4. WY regulations (Chapter 5, Section 3 (b) (ii)) require environmental monitoring of AVFs to help determine if the essential hydrologic functions are being maintained. The monitoring proposed by Brook is not adequate as it is based only on annual infrared photos of the Tongue River alluvial floodplain along the southern boundary of the permit application and does not include the declared AVFs downstream of the BHC mine property. It is unclear if the WDEQ AVF determination in the January 10, 2020 letter removes this requirement or does Brook need to do this?

DETAILED COMMENTS

Land Use - Appendix D1

1. The population data for Sheridan and Dayton are from 2012. Application should provide current data.

2. The economic agricultural statistics for Sheridan County are from 2007. Application should provide current data.

Climatology - Appendix D4

1. Like other baseline data the climatological data is not current -but based on data from 2000 – 2005. It is important to provide current precipitation and temperature data

Hydrology - Appendix D6

<u>Surface water monitoring / baseline characterization</u>

1. The permit application provides steam discharge data from two USGS stations located on the Tongue River near Monarch (USGS 06299980) and at the WY-MT state line (USGS 06306300) and two USGS stations located on Goose Creek below Sheridan (USGS 06305500) and near Acme (USGS 06305700). Data from these sites cannot be used to compare conditions upstream of the mine permit area with conditions downstream of the mine permit area. There is no monitoring station on the Tongue River above the mine permit area. The stream discharge data for these stations presented in Table D6.1-3 are not current. The most recent data from the Tongue River stations and the Goose Creek station near Acme is 2017. The most recent data for the Goose Creek station below Sheridan is 1984. The USGS monitoring station 06306300 is located at the WY-MT state line and is almost 30 miles below the mine permit area. There is no data since 1984 for the USGS station on Goose Creek below Sheridan (06305500) and the station on Goose Creek near Acme is too far upstream.

2. Discharge data is provided for Tongue River station TR03 established by the Sheridan County Conservation District. StationTR03 is located approximately 2-3 miles

downstream of the mine permit area. This is an appropriate location, but the streamflow data are very sparse, May-Aug 2013 and May-Sept 2017.

3. Discharge data is provided for two Bighorn mine monitoring locations – TR2B80, located on the Tongue River downstream of mine permit area and HWC1-79, located on Hidden Water Creek. Again, the data are very sparse and somewhat qualitative. Data from TR2B80 are from May 2016-April 2018 and data from HWC1-79 are from 1982-1998.

4. The permit application (Section D6.1.3.1) refers to a USGS gage on Slater Creek. This station is shown on Exhibit D61-1 however, it is not included on Table D6.1-2 or Table D6.1-2.

5. Figures D6.1-3 and D6.1-4 indicate great difference in June high flow between 2016 (>500 cfs) and 2017 (>2000cfs). There is no discussion / explanation for this difference.

6. Two surface water monitoring locations were established for background characterization on Slater Creek (SM578418-SW-1 and SM578512-SW-1) and two on Hidden Water Creek (SM578415-SW-1 and SM578409-SW-1). Streamflow and water quality data from these sites is very limited. The data presented in the revised permit application are Sept-Oct 2013 and April – Sept 2014. No flow data for Slater Creek or Hidden Water Creek was obtained from Oct-March (6 months) – because the monitoring equipment was removed for winter. The baseline monitoring period was too short and is now out of date for all four baseline locations. The lack of seasonal data precludes the establishment of annual hydrograph. Current stream flow and water quality should be obtained from these locations prior to mining. The revised permit application (Page D6-9) states that site visits to these 4 locations were conducted after all 2-year 24 - hour storm events. Where is this data?

7. It has been reported that the USGS monitoring station at Monarch has been discontinued. Is this true? If so -will a new site be established? In response to this concern Brook committed to find another location. Apparently, this has not been done. Streamflow and water quality sampling stations should be established on the Tongue River upstream and downstream of permit area (within ½ mile of permit boundaries).

8. Surface water quality data presented in the revised permit application is insufficient to characterize background / ambient water quality. Very little new surface water quality data is presented. There is no current water quality data for Slater Creek or Hidden Water Creek. The sampling site on Goose Creek is located too far from the confluence of Goose Creek with the Tongue River. Data from the two new sites on the Tongue River (578420-TR-1& 578524-TR-1) can be useful for characterizing baseline conditions if sampling continues at quarterly intervals for a full year. There is no discussion /assessment of the data. The permit application (page D6-13) indicates that water quality data from the USGS station 06299980 at Monarch was reviewed, however this data is not provided. Water quality data discussed in the permit application include:

a. data from two locations on Slater Creek collected in April 2014. These data do not represent current conditions.
b. data from Goose Creek – quarterly sampling from April 2015 – June 2016.
c. data from 13 sites (6 on the Tongue River and 7 on Tongue River tributaries) included in the 2017 SCCD report. The data are from 2016 and only include data for temperature, dissolved oxygen, pH, turbidity, conductivity and E. *coli* bacteria. These data are of limited value for evaluating potential impacts from coal mining. There are no data for ions or metals.
d. data from TR03 provided from Bighorn mine - June 2016 – March 2018
e. data from three sites from which grab samples have been collected in 2018 for water quality analyses. Two of these sampling sites (578420-TR-1& 578524-TR-1) are located adjacent to monitoring wells in the Tongue River alluvium and the Carney coal. A third sampling site 578513-IRR-DITCH-1 is an irrigation ditch located north of the Tongue River. Water quality data is presented for April, June and July,2018
f. data from Hidden Water Creek – 9 samples from 1979-1989

9. There is no water quality data for the Tongue River upstream of station 578525-TR-. The mine permit area extends west of this point. There should be a sampling site upstream of the western boundary of the mine permit area.

10. Page D6-11 – the revised permit application should include more specific information on the TMDLs established for the Tongue River and Goose Creek – what are the constituents of concern? What is the reach of the River / Creek? What is the TMDL limit that has been established for Goose Creek?

<u>Groundwater monitoring / baseline characterization</u>

11. In the original permit application, there were nine groundwater monitoring locations that were used to obtain background / baseline data. These included nine Carney wells, nine Masters wells, three alluvial wells (along Slater Creek), one underburden well and one well screened in both the Carney and Masters coal seams. The revised permit application relies primarily on these same data for characterizing baseline groundwater conditions. The hydrographs and water quality data provided for these wells only include limited data from 2013-2014.

12. In 2018, seven new groundwater monitoring wells were installed: two wells in Tongue River alluvium (578524 – AL-1 & 578420-AL-1); two wells in the Carney that are co-located with the two new alluvial wells (578524 – CRN-PUMP & 578420-CRN-PUMP): two wells in the Bighorn spoils (578415 – SPL-1 & 578415 – SPL -2); and one overburden (578513 – OVB-1). Well 578420-AL-1 is on south side of the Tongue River and apparently only sampled twice and then abandoned. Well 578524 – CRN-PUMP was only sampled once and then abandoned. In addition, it should be noted that the hydrographs for these wells are for very limited time periods -one to four months. There is no discussion of the rational for these well locations or what data will be obtained and

how / why the data is useful to address the WEQC Findings. These data are clearly inadequate for characterization of baseline groundwater and surface water hydrology. In 2019 Brook installed a third well in the Tongue River alluvial aquifer. downgradient of wells 578524 – AL-1 & 578420-AL-1. Howeveronly two water level measurements are provided for this well.

13. The well construction logs for wells 578524 – AL-1 and 578524– CRN-PUMP (Addendum D6-7) are very inconsistent even though the two wells are co-located. The log for alluvial well (578524 – AL-1) indicates about 27 feet of alluvial gravel and an underlying sandstone while the Carney well (578524– CRN-PUMP) indicates only 15 ft of alluvium and does not indicate an underlying sandstone. These differences need to be resolved.

14. Section D6.2.1.1states that recharge and discharge areas for the Masters and Carney aquifers are shown on Exhibits D6.2-2 and D6.2-3. These areas are not shown on these Exhibits.

15. The saturated zones maps (exhibits D6.4 thru D6.2-8) were compiled using a very limited and old data set from 2013 - 2014. These maps should be developed with current data collected over an annual hydrograph to assess seasonal variation. In the 2018 SAP Brook committed to submit the supporting info used to determine saturation zones including well names, geologic info, well depth and methodology. This information is not in the revised permit application. Why didn't Brook use saturation zone maps to locate monitoring wells? Brook says they did not and they don't need to?

16. Four of the original monitoring wells - 578417- MST, 578417- CRN, 578408 – MST and 578408 – CRN were installed in two -inch coreholes, using bentonite for isolating sampling intervals. This is a poor design for a groundwater monitoring well and is not compatible with any technical guidelines regarding construction of groundwater monitoring wells. This results in uncertainty regarding water level measurements and water quality sampling results.

17. The data and discussion regarding recharge, flow and discharge from the Tongue River member is very inadequate. The coal lithologies and sandstones within this member are the primary water-bearing units, while finer rained lithologies between the coal beds are typically minimally saturated. Lithologic logs indicate that a significant sandstone unit above the Carney seam which thickens to the east and is often saturated. Aquifer test data from BHC indicate production rates of 38 gpm from sandstones above the Carney. There needs to be a much better discussion of the estimated annual recharge to the Tongue River member including recharge via infiltration at outcrops and clinker areas as well as groundwater inflow to the Tongue River member from areas upgradient of the mine permit areas. The cross-sections indicate faulting with up to tens of feet displacement that vertically separates the permeable lithologic units in the Tongue River member. This likely results in more local groundwater flow systems that have somewhat distinct discharge locations. There is some revised discussion of recharge mechanisms to the Carney coal seam along western 2/3 of mine permit area and subsequent flow

downgradient, however the discussion of discharge from the coals and sandstone lithologies included Section D6.2.2.5 and Section 2.6.1 in Addendum MP-3-2 is very qualitative and not supported by any data. In this hydrogeologic setting – dewatering the coal seams for mining may impact groundwater flow in the saturated sandstones /siltstones and subsequently impact discharge to the Tongue River alluvium.

18. It is clear from the EQC Findings that the hydrogeology of the Tongue River alluvium was not adequately characterized in the original Brook mine permit application. This is important because the Tongue River alluvial deposits comprise the alluvial valley floors. Pursuant to WS 35-11 406 (n) (v), a coal mining operation may "*not materially damage the quantity or quality of water in surface water or underground water systems that supply these alluvial valley floors*". In response the EQC findings, Brook extended cross-sections D-D', E-E', F-F', G-G', I-I' and L-L' southward past the Tongue River. However -the cross-section extensions were compiled using old, poor lithologic data from existing water wells. The SEO permit data for these types of wells is often of very poor quality. WDEQ-LQD should require Brook mine to verify the cross-sections with data from new drilling. This is necessary to substantiate the statement on page D5-8 that *"Most of the geologic cross sections demonstrate there is no hydraulic connection between targeted coals and the Tongue River".* The permit application does not include any analysis to support this statement.

19. As stated above only two new Tongue River alluvial wells were installed in 2018. One of these wells (578420-AL-1) was abandoned after only two rounds of water level measurements and water quality sampling. The other new well (578524 – AL-1) was constructed in a more appropriate location however, the data from this well is also very limited.

20. Due to the potential for impacting AVFs on the Tongue River alluvium and the need for mining and post-mining monitoring, Brook should construct a water table map for the Tongue River alluvial aquifer. A water table map would aid in establishing baseline water level and direction / velocity of flow in the alluvial aquifer. The water level contours shown on Exhibit D6.2-3 are based on water level measurement form only two well locations and the two wells are on opposite sides of the Tongue River. It is necessary to have water level data from at least three locations on the north side of the Tongue River to prepare, even a simple water table map Because of this the water level contours presented in Exhibit D6.2-3 are not representative.

21. The revised permit application does not present a sound basis for the assumption that ground water in the Tongue River alluvium discharges to the underlying coal – The second quarter 2018 groundwater level elevation (Table D6-1-Addendum D6-9) in well 578520-CRN-PUMP was higher than the water level elevation in co-located alluvial well 578520-AL-1. Groundwater level elevations were also very similar for wells 578524-CRN-PUMP and the co-located alluvial well 578524-AL- 1. This indicates flow from the coal to the alluvium. There is no comparable water level data for areas west of well 578524-AL-1. As shown in cross section L-L' (Addendum D5-3) the Tongue river member of the Ft. Union formation underlies the Tongue River alluvium adjacent to the

western part of the mine permit area. As shown in the cross-section the Carney and Masters coals seams occur within a few to tens of feet below the bottom of the alluvium. If the vertical gradient is upward -ground water will flow from the Tongue River member into the alluvial aquifer. In addition the cross section shown in Addendum MP-3 -Figure 2.3-3 depicts discharge of groundwater from the Carney coal to the Tongue River alluvial aquifer.

22. The aquifer property data obtained from BHC pump tests / slug tests in the spoils is not suitable for characterizing aquifer properties for the Tongue River alluvial aquifer. The spoils are essentially anthropogenic fill and groundwater flow in these spoils is likely quite different than groundwater flow through the coarse sand and gravels which comprise the Tongue River alluvial aquifer.

Aquifer tests

23. The revised permit application includes the same 2013-2014 baseline data / information regarding aquifer testing that was included in the original permit application and limited aquifer test data from 2018. The 2013-2014 tests were conducted primarily to assess hydraulic properties of coals to be mined. The wells chosen for the aquifer testing are located in the far east end of the permit area and, given the variability in saturated conditions and water quality in the coal seams, it is unknown if the results from these wells are representative of hydraulic properties of the coal seams to the west. The Slater Creek alluvial monitoring wells were not monitored during the aquifer tests. This was a serious omission. As determined by WDEQ there are AVF lands within the Slater Creek valley which might be impacted. To evaluate potential impacts to the Slater Creek AVF an aquifer test (pumping the coal aquifer and monitoring the saturated alluvium) should be conducted near the saturated Slater Creek alluvium.

24. In June 2018 two aquifer tests were completed at locations 578524 and 578520. These tests were conducted to evaluate effects of pumping the Carney coal on water levels in the overlying Tongue River alluvium. For the test at location 578524, the Carney well was pumped at 4 gallons per minute (gpm) for 24 hours. There was no reported effect on the water level in the co-located alluvial well 578524-AL-1. It is likely that the Carney well was not pumped at a high enough yield and was not pumped long enough to stress the alluvial aquifer. This significantly constrains the usefulness of this data. The June 2018 aquifer test at location 578520 was aborted and no useful data were collected. The limited water level, water quality and pump test data from the two new Tongue River alluvial wells is not sufficient to adequately characterize the hydrogeology of the Tongue River alluvium and the nature of the hydraulic relationship between groundwater in the alluvial aquifer and groundwater in the coal seams north of the Tongue River or surface water in the Tongue River. Sampling and monitoring need to continue for at least a full year and water level and water quality data need to be obtained from locations west of 578524.

25. The revised permit application includes hydraulic property data from aquifer tests at 33 locations conducted by BHC in 1979-1981. Hydraulic data are presented for the Tongue

River alluvial aquifer, the Dietz and Monarch coal seams and spoils BHC mine. The permit application provides a comparison of hydraulic conductivity data from BHC aquifer testing and Brook aquifer testing. This comparison has limited usefulness. The BHC tests were conducted in different hydrogeologic units than the Brook tests. Hydraulic conductivity values vary significantly. The 33 BHC locations are east of the Brook mine permit area and have limited value for establishing baseline conditions in the Tongue River alluvium to the west. Brook has not conducted any aquifer testing in the Tongue River alluvial aquifer and no aquifer property data are presented for this aquifer west of the BHC properties.

26. Table D6.2-2 includes data for 18 slug tests performed in March, April and June 2018. (Six Carney wells, five Masters wells and five alluvial wells. There is no discussion of the data from these tests in Section D6.2.2.2 or Addendum D6-8.

27. There is no data regarding the vertical hydraulic conductivity in the Tongue River member or the Tongue River alluvium. This data is important for helping evaluate the hydraulic relationship between the coals seams and overlying alluvial deposits along Slater Creek and the Tongue River. Brook committed to providing this but has not provided.

<u>Groundwater levels</u>

28. The revised permit application includes pre-mining potentiometric surface maps (Exhibits D6.2-2 and D6.2-3) for the Masters and Carney seams. These maps were constructed based on computed average water levels using water level data from 2013-2014. The potentiometric surface contours presented on the two maps are very similar as are flow directions which indicate groundwater flow towards the Tongue River and /or the Tongue River alluvium. The maps also indicate a steep gradient. Based on the use of "*computed average water levels*" and the fact that the data is 5-6 years old, there is significant uncertainty as to how representative these maps are of the current potentiometric surface. The revised permit application does not include any update of these maps.

29. The 2018 potentiometric surface elevation data from 578524– CRN-PUMP and 578520 – CRN-PUMP is not at all useful. There is only one measurement from well 578524 – CRN-PUMP and two from 578520 -CRN-PUMP. Table D6-1 (Addendum D6-9) indicates that well 578524– CRN-PUMP was plugged and abandoned after only one measurement. Why was this well abandoned? This severely limits the availability to obtain trend data in the future.

30. The information contained in the revised permit application regarding the impact of the development of coal bed natural gas (CBNG) on the potentiometric surface elevations in the Carney and Masters coal aquifers within the proposed permit area is confusing and incomplete. On page D6-31 the revised permit application states that *"it is unlikely that the CBNG dewatering efforts have significantly affected water levels in the wells utilized for the aquifer tests"*. On page D6-35 the revised permit application states *that "CBNG production has affected the potentiometric surface prior to baseline monitoring on the* *eastern edge of the permit area".* In Addendum MP-3 (page MP-3-20) it states that "*withdrawals from the aquifer system for coal bed methane (CBM) production are believed to have impacted water levels in the coal seams"* and *"the volume of recharge entering the model laterally from adjacent aquifers is minimal because CBM development has significantly decreased water levels in the coal aquifers".* Since the groundwater modeling was focused on declines in the potentiometric surface of the coal seams due to dewatering – it is obvious that this refers to the western part of the mine permit area. The information in the revised permit area is incomplete and inadequate for assessing the affect of CBNG dewatering on the current and future of water levels in the coal seams to be mined. This needs to be considered when conducting a CHIA. Recent water

31. The discussion regarding saturation zones (D6.2.2.7) is incomplete. Most of the Carney coreholes listed in Tables D6.2-24 (Carney), D6.2-25 (underburden) and D6.2-26 (Slater Creek alluvium) indicate partial or fully saturated conditions. There is no discussion of when the measurements were taken or if they represent a full hydrograph or just a single measurement.

Groundwater quality

32. The revised permit application does not include an adequate analysis /discussion of the groundwater quality data. There was no sound rational for the selected sampling locations in the Tongue River alluvial aquifer and the Carney coal aquifer. As shown by the piper diagram in Figure D6.2-2 there is a lot of variability in the ground water quality between geologic /aquifer units. The explanation for these differences presented on in Section D6.2.3 is very qualitative and general and not adequate for establishing baseline.

33. The piper diagram presented in Figure D6-2-3 indicates that the ion chemistry of the groundwater from the Carney wells is similar to the ion chemistry of groundwater from the two Tongue Rive alluvial aquifer wells. This may indicate mixing of groundwater from the Carney with groundwater in the alluvial aquifer.

34. The revised permit application provides 2013-2014 ground water quality data from four Carney wells, four Masters wells, three Slater Creek alluvial wells and one underburden well. These data are very limited and outdated.

35. Ground water quality data are presented for six of the seven new wells installed in 2018. Well 578524 – AL-1was sampled four times; wells 578420-AL-1, 578420-CRN-PUMP and 578415 - SPL -2 were sampled two times; wells 578524 – CRN-PUMP and 578415 – SPL-1 were sampled one time.

36. Six samples were collected from only two locations for the Tongue River alluvium and collected over a very short time period and not over a full annual hydrograph. These data are not adequate for characterizing spatial and seasonal differences in water quality. These two wells are located south of the eastern part of the mine permit area and may not be representative of the alluvial aquifer upstream to the west.

37. Water quality in the Carney (578420-CRN-PUMP; 578524 – CRN-PUMP) from 2018 samples is much different / better (based on TDS, sulfate, bicarbonate) than 2013-14 data. There is no discussion or explanation for this difference.

38. As stated previously wells 578524 – CRN-PUMP and 578420-AL-1 have been plugged and abandoned so there can be no future sampling. Why were these wells abandoned?

39. The conclusions regarding the hydraulic connection between Slater Creek alluvium and underlying Carney coal are based on one ground water quality sample and based entirely on the interpretation that the two water bearing units have slightly different water types. This is poor interpretation of very limited data.

Groundwater Model

40. While the MODFLOW model is an excellent model, the results have a high uncertainty because the model simulations and predictions were derived based on limited site-specific data and broad assumptions:
    a. The 2013-2014 hydraulic properties data provided by Brook mine were obtained from only one location in the far east part of the mine permit area and for some parameters, average values or literature derived values were used for all nodes.
    b. The slug test data obtained in 2018 are useful but eleven of the 16 slug tests were conducted using coal wells and only one slug test was conducted using a Tongue river alluvial well.
    c. Limited hydraulic property data was obtained from a pump test conducted at location 578524. The pump test attempted at location 578520 was aborted.
    d. Aquifer parameters for the under and interburden zones were not measured through pumping tests for the Brook Mine Project.
    e. The model applies a single storage coefficient to each layer and used no site-specific porosity data -but an assumed 10%
    f. Annual and seasonal recharge was not considered quantitatively but assigned a single regional value and adjusted in calibration.
    g. The top layer for the model combined the alluvial deposits, the spoils at the BHC facility and the overburden (Tongue River member lithologies above the Carney seam). These three types of deposit have significantly different hydraulic properties and combining them is inappropriate.
    h. It is clear from the hydraulic data presented in Addendum MP-3 that the alluvial aquifer and the coal aquifers vary significantly within each aquifer. This implies significant heterogeneity – which the model design and assumptions do not accommodate.
    i. The model assumed that groundwater flow was "Darcy flow" – through homogenous geologic conditions. However there is significant heterogeneity and groundwater flow in the coals most likely occurs under fracture flow conditions.

41. Modeling the current CBM affected coal seam water levels as static is far too simplistic. If the drawdowns from CBM production have caused the coals to be partially saturated what will happen if the water levels recover in areas where coal has been removed? The modeling indicates groundwater level recovery of 90% after 10 years for the Carney and 20 years for the Masters. This does not account for water level fluctuations due to CBM production.

Alluvial Valley Floors - Appendix D11

1. As with much of the text in this permit application the text in Section D11.1 is outdated. Brook mine concludes that there are no AVFs in the Slater Creek drainage and therefore did provide information to satisfy the requirement pursuant to WS 35-11 406 9 (n) (v) that mining *not materially damage the quantity or quality of water in surface or underground water systems that supply these alluvial valley floors* above requirement. However, WDEQ has made a determination that there are about 13 acres of AVF in Slater Creek. This determination is described in a January 7, 2016 LQD staff memorandum and confirmed in a January 10, 2020 letter from the Acting WDEQ Administrator to Randall Atkins, WWC.

2. The WDEQ, in the CHIA, only recognizes declared AVFs on the Tongue River downstream of BHC mining property. However, both Brook and WDEQ agree that the alluvial sediments underlying the flood plain along the north side of the of the Tongue River are potential AVFs. Exhibit D11.1-1 clearly indicates potentially sub-irrigated lands occur along the north side of the Tongue river adjacent to the mine permit boundary. On page D11-1 the permit application states that "*Based on data presented herein, the Tongue River valley in the areas studied by RAMACO, appears to be an AVF. Portions of these areas are within the Permit area; however, no surface disturbance or mining is proposed there. As such, no material damage is anticipated to this AVF".*

3. When lands classified as alluvial valley floors will be affected by mining, LQD is required to evaluate whether any anticipated interruption or disturbance will be significant to a farm's agricultural production. Chapter 3, Section 2(f) of the Land Quality-Coal Rules outlines the approved test for measuring significance to farming. In the January 10, 2020 letter the WDEQ Administrator informs Brook that pursuant to WS 35-11 406 9 (n) (v) (A) *LQD does not identify any potential for mining to interrupt, discontinue, or preclude agricultural activities on lands identified as AVFs* Because no lands classified as AVFs will be affected, the test for significance to farming is unnecessary. This finding is based on Brooks conclusion that no AVFs will be affected because there will be no surface disturbance on AVFs and that there is little or no farming on the AVFs. This conclusion relies on incomplete information regarding current and future farming activities. In addition, there is not adequate discussion of potential impact that could occur from trench / highwall mining to the north of the Tongue River, which could reduce / alter discharge from the Tongue River Member of the Ft. Union Fm., (including the sandstones and coal seams) to the Tongue River or Tongue River alluvium. This is directly related to one of the three

"essential hydrologic functions" established by the WDEQ – *"ability to transmit groundwaters of suitable quality and quantity, to support sub-irrigation of certain areas"*. Brook mine concludes that there is no discharge from the coals and sandstones in the Tongue River member to the Tongue River or Slater Creek alluvium. However, neither the permit application nor the CHIA have presented any quantitative data that supports this conclusion. The cross-sections included in Appendix 5 indicate that the Carney and Masters coals occur only a few feet beneath the Tongue river alluvium. The cross-sections are based on very limited data and do not provide much detail on the lithologies and preferential flow paths that would allow upward flow of water from the coals to the alluvium. The cross section shown in Addendum MP-3 -Figure 2.3-3 depicts discharge of groundwater from the Carney coal to the Tongue River alluvial aquifer.

Operational and Post-Mining Water Resource Monitoring

1. A sampling and analysis plan should be provided for the operational water resource monitoring program.
2. It is very unclear if all the proposed monitoring locations, for both the operational and post-mining water resource monitoring programs, are currently accessible and usable. Most of monitoring wells and surface water stations were established 15 years ago and may have been degraded or modified.
3. Table MP.7-1 lists 19 operational surface water monitoring locations that will be sampled for water quality on a quarterly basis. Has Brook committed to this? Will the data be available to the public?
4. Table MP. 7-3 includes a number of proposed operational monitoring locations for the Masters coal seam and former BHC monitoring locations. With the new mine plan, will these locations remain in the monitoring program?
5. On page MP-58 the revised mine plan states that, during mine operation, surface water quantity data in the form of peak daily flow rate will be measured continuously at 4 locations between April and October. Has Brook committed to this? How will this be verified?
6. The nine alluvial wells listed in Table MP.7-4 include only one existing well in the Tongue river alluvium (578524-AL-1). Monitoring well 578520 -AL has been abandoned and monitoring well 578415 – AL is proposed but has not been installed. One monitoring well in the Tongue River alluvial aquifer is not adequate.
7. On page MP-61 the text states that "*In the event that a groundwater monitoring well is discontinued or damaged during the mining process, it will be replaced with another monitoring well so that the total number of working groundwater monitoring wells remains the same"*. The application should identify the monitoring wells that may be destroyed by mining. How will this be verified? Will WDEQ be advised?
8. The post-mining monitoring program that is discussed in Section RP.8.4 of the Reclamation Plan is inadequate.
   j. Section RP.8.4.1 states that groundwater monitoring will consist of annual water level monitoring and water quality sampling until a *"definite trend is established"* Establishing a trend with only annual monitoring could take many years. There is a real concern that Brook mine will not monitor long enough to establish trends.

k. No information is provided regarding the criteria that will be used by WDEQ to determine if water quality and water levels are suitable for release of Brook's bond. What constitutes compliance?

l. On page RP-41 the text states that *certain water quality parameters will be eliminated as data indicate*. There should be an explanation of what criteria will be used to decide to eliminate a water quality parameter.

m. Section RP.8.4 indicates that the pump tests will be conducted in the backfilled spoil to determine transmissivity and storage coefficient. There is no discussion of acceptable values for these parameters and what mitigation would be required if these values are not obtained. There is also a concern that water levels in the monitoring wells will not recover for many years – so conducting the pump tests may not be possible.

n. There is no discussion or plan provided for "post-mining inspections"

SELECTED REFERENCES

September 28, 2017 – Wyoming Environmental Quality Council - *Findings of Fact, Conclusions of Law and Order, Re: Brook Mine Application TFN 6 2-05, Docket 17-4802*

December 2017, *2016 Tongue River watershed Monitoring Project Final Report, Sheridan County Conservation District*

January 18, 2018 – Letter from BJ Kristiansen, WDEQ to Jeff Baron, WWC Engineering (Brook), Re: *Brook Mine Hydrologic Monitoring and Testing Proposal Related to Addressing Environmental Quality Council (EQC) Findings and Order for TFN 6 2/025*

February 2108 - *2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order*, prepared by WWC Engineering for Ramaco

February 26, 2018 – WDEQ Memorandum from Muthu Kuchanur and Matt Kunze to BJ Kristiansen, Re: *First Round Comments on February 2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order (TFN 6 2/025)*

July 20, 2018 –Letter from Jeff Barron, WWC Engineering (on behalf of Ramaco) to BJ Kristiansen, WDEQ Re*: Round 1 Comment Responses for 2018 Hydrology and Subsidence Sampling and Analysis Plan (SAP) TFN 6 2/025*

July 30, 2018 – WDEQ Memorandum from Muthu Kuchanuv and Matt Kunze to BJ Kristiansen Re*: Second Round Comments on February 2018 Hydrology and Subsidence Sampling and Analysis Plan to Address Environmental Quality Council Findings and Order (TFN 6 2/025)*

October 19, 2018 – Revised Permit to Mine Application TFN 6 2/025, Ramaco Wyoming Coal, LLC