Appalachian Mining & Engineering, Inc.

Geolab Materials Testing

March 29, 2022

Mr. Nick Mason, *Mine Engineer*
Allegiance Coal Limited
12250 Hwy 12
Weston, Colorado 81091

Re: Analysis of Multiple Seam Stress Distribution and Pillar Stability at the New Elk Mine

Dear Mr. Mason,

The objective of this study is to examine the multiple seam stress distribution and pillar stability for proposed development mining within the Blue seam at the New Elk mining operation. Given the deep cover and multiple seam conditions present at the New Elk mine, Mr. Nick Mason (*Mine Engineer*) of **Allegiance Coal Limited** (**AC**) requested that **Appalachian Mining & Engineering, Inc.** (**AME**) evaluate the multiple seam stress distribution and pillar stability in relation to the proposed New Elk development mining (Blue seam) which has been underlain by previous mine works in the Maxwell seam. Stress distribution and pillar stability analyses were conducted using the widely accepted ACPS (Analysis of Coal Pillar Stability) program. Input parameters were derived from mine mapping and core hole data as provided by **AC**.

A review of ACPS results indicate that in areas where development mining in the Blue seam overlays previous development works within the Maxwell seam, the proposed 55-foot by 55-foot pillars result in a minimum pillar stability factor of 1.40 with the majority of the proposed pillars maintaining a stability factor greater than 2.0. In areas where development mining in the Blue seam crosses gob-solid boundaries defined by secondary recovery within the Maxwell seam, it is recommended that pillars be lengthened to 55-foot by 110-foot centers by dropping the cross cut resulting in stability factors greater than 2.0 recommended for long term pillar stability. Given that mining within the Maxwell seam has a radial stress influence on the overlying Blue seam, it is recommended that pillars be lengthened one row inby, at, and outby the

location of the gob-solid boundary. These recommendations have been confirmed through additional ACPS analyses.

Based on multiple pillar stability analyses conducted using the ACPS program, the proposed pillar layout is provides a pillar stability factor of 2.0 as recommended by NIOSH for long term stability. Given the categorization of long term stable pillars, it is highly unlikely that development mining at the New Elk mine will initiate surface settlement as a pillar stability factor of 2.0 provide long term stability to the immediate and main roof.

Nick, if you have any questions, comments, or concerns as you and others review this report, please contact me at (859)263-8899 or by email at cnewman@ame-geolab.com.

Sincerely,

Appalachian Mining & Engineering, Inc.

Christopher Newman

Digitally signed by Christopher Newman
DN: cn=Christopher Newman, o=Appalachian Mining and Engineering, Inc., ou, email=cnewman@ame-geolab.com, c=US
Date: 2022.05.02 11:56:14 -04'00'

Christopher Newman, Ph.D.
Geomechanical Engineer

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Appendices

I. Introduction and Background

Fifteen (15) entry room-and-pillar panels have been proposed for the development of the Blue seam at the New Elk mine owned and operated by **Allegiance Coal Limited** (**AC**). Given the deep cover (depth > 1,000-feet) and multiple seam stress conditions present at the New Elk mine, Mr. Nick Mason (*Mine Engineer*) of **AC** requested that **Appalachian Mining & Engineering, Inc.** (**AME**) evaluate the proposed room-and-pillar panel layout. Proposed mining in the Blue seam will result in overmining of mine works in the Maxwell seam approximately 200-feet below the Blue seam. Therefore, the ACPS program was used for the analysis of multiple seam stress distribution and pillar stability for proposed New Elk mine works in the Blue seam in relation to gob-solid boundaries located in the underlying Maxwell seam. Multiple seam stress distributions and pillar stability analyses were conducted across unique twenty (20) stress conditions present at the New Elk mine using the widely accepted ACPS (Analysis of Coal Pillar Stability). Input parameters for ACPS were derived through a review of geologic and geologist logs, seam structure and orientation, varying surface topography, as well as mine mapping as provided by **AC** Engineering, as this is the operational height required for equipment operation.

Based on a review of 37 drill holes in the area of proposed mining at the New Elk mine, the Blue seam has an average coal height of 4.35-feet with a maximum coal height of 6.87 with a dip of 1.80% across the area. Given the limited coal seam thickness, it is not likely that a 2.5 clean ton per linear foot of mining advance assuming an equivalent 6 raw ton per linear foot of mining advance based on current mining conditions and plant throughput as provided by **AC** Engineering. Therefore, all analyses have been conducted based on a 6-foot mining height at the New Elk mine. The limiting design factor of a 6-foot mining height was provided by **AC**.

II. Approach and Methodology

2.1 Stress Distribution and Pillar Stability Analysis

The evaluation of multiple seam stress distribution and pillar stability for the development of the Blue seam was conducted using ACPS (Analysis of Coal Pillar Stability), a coal pillar analysis program developed by Dr. Christopher Mark and Dr. Zach Agioutantis. The ACPS program integrates ARMPS (Analysis of Retreat Mining Pillar Stability), ALPS (Analysis of Longwall Pillar Stability), and AMSS (Analysis of Multiple Seam Pillar Stability) of the National Institute of Occupational Health and Safety (NIOSH) Ground Control Toolbar into a single and centralized application.

Twenty (20) ACPS analyses were conducted for the proposed room-and-pillar panels to cover the variety of multiple and single seam stress scenarios present. However, it should be noted that the ACPS program allows for a maximum of 11 entry panels. Therefore, to obtain a representative pillar layout for the proposed New Elk pillar layout, ACPS parameters were modified with respect to the “One active section & two side gob” loading condition with extent of active gob set to zero (0). The barrier pillar between the first and second “side gob” was defined with a width of 35-feet and 35-foot wide “leave pillars” for Row A and Row B. The results of the ACPS analyses are presented in Appendix I. Where the proposed 55-foot by 55-foot pillar layout did not meet the 2.0 recommendation for long term pillar stability, an alternative pillar layout was evaluated and has been designated with the letter “A”.

The analysis of multiple seam stress distribution and pillar stability for the New Elk mine was developed based on the following information;

- Surface contours (**AC**),
- Core logs (**AC**),
- Location and layout of old mine works (**AC**),
- Proposed mine projections (**AC**),
- Mine survey data (**AC**), and
- In situ coal strength of 900-psi.

III. Stress Distribution and Pillar Stability Results

3.1 ACPS Pillar Stability Results

The fifteen (15) entry production panel layout with 55-foot by 55-foot pillars on center, 18-foot entry width, and 6-foot mining height were evaluated through a series of ACPS single and multiple seam stability analyses. A total of twenty (20) unique analyses were conducted with twelve (12) multiple seam stress conditions evaluated in areas where proposed development in the Blue seam resulted in overmining of previous mine works in the Maxwell seam and eight (8) single seam development only mining conditions. Overburden depth and the interburden thickness for the Blue and Maxwell seams were defined based on seam gird calculations developed from drill holes and core logs provided by **AC**. The in situ coal strength was defined as the default 900-lbs/in^2 with the pressure arch factor as defined by the ACPS program. ACPS multiple seam pillar stability results are available in Appendix I. For loading scenarios in which the proposed pillar dimensions of 55-foot by 55-foot did not meet the required 2.0 for long term pillar stability, the minimum pillar length to achieve the recommended pillar safety factor has been provided.

Based on a review of the ACPS pillar stability results for both multiple seam and single seam stress conditions, it is recommended that the length of production pillars be increased to 110-feet (on center). Operationally, this would involve dropping a single crosscut between proposed pillars. It should be noted that stress impacts on the Blue seam as a result of multiple seam mine works in the Maxwell has a defined area of influence controlled by a theoretical abutment angle commonly assumed to be 21-degrees. Therefore, it is recommended that pillars are extended one break outby and one break inby the point at which development mining in the Blue seam overmines a gob-solid boundary within the Maxwell seam.

IV. Summary and Conclusions

The stress distribution and pillar stability analyses presented in this report were developed based on core logs, mine mapping, survey data, and surface contours as provided by **AC**. The in situ coal strength used for both ACPS analyses were defined with respect to the default 900-psi. Multiple seam stress distribution and pillar stability analyses indicate that the proposed 50-foot by 50-foot production pillars do not meet the

2.0 pillar safety factor recommendation for long term stability in areas where development in the Blue seam overmines gob-solid boundaries within the Maxwell seam. In these areas, it is recommended that pillar be lengthened for 110-feet outby, at, and inby the location of gob-solid boundary crossings. Following adjustments to the pillar length, ACPS results for both single and multiple seam stress conditions indicate pillar safety factors greater than the recommended 2.0 for long term stability. Given a pillar stability factor of 2.0, it is highly unlikely that development mining within the Blue seam would initiate surface subsidence.

V. References

1. Heasley, K.A. (1998), Numerical Modeling of Limestone Mines with a Laminated Displacement-Discontinuity Code, Ph.D. Dissertation, Colorado School of Mines, p. 187

Appendix I

ACPS Input Parameters and Stability Results

Table 1: ACPS Input Parameters and Results for the Proposed Pillar Layout at New Elk

Scenario	High Average Depth of Cover (ft)	Number of Entries	Width Entry (ft)	Height Mining (ft)	Width Pillar (ft)	Length Pillar (ft)	Conditions Stress	CMRR	Interburden Thickness (ft)	Seam Thickness (ft)	Remnant Pillar Width (ft)	Gob Width 1 (ft)	Gob Width 2 (ft)	ACPS SF
1	350	7	18	6	75	100	Development	-	-	-	-	-	-	6.53
2	300	7	18	6	55	75	Development	-	-	-	-	-	-	4.43
3	425	15	18	6	55	55	Gob-Solid	35	255	5	-	620	-	2.09
4	675	15	18	6	55	55	Remnant Pillar	35	255	5	185	620	620	1.76
5	675	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	1.40
6	325	15	18	6	55	55	Gob-Solid	35	257	5	-	620	-	2.39
7	475	15	18	6	55	55	Remnant Pillar	35	260	5	185	620	620	1.60
8	550	15	18	6	55	55	Gob-Solid	35	265	5	-	620	-	1.57
9	450	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	1.85
10	540	15	18	6	55	55	Remnant Pillar	35	260	5	185	620	620	1.44
11	600	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	1.45
12	760	15	18	6	55	55	Development	-	-	-	-	-	-	1.50
13	300	15	18	6	55	55	Gob-Solid	35	260	5	-	620	-	2.55
14	350	15	18	6	55	55	Remnant Pillar	35	265	5	180	620	620	2.00
15	425	15	18	6	55	55	Gob-Solid	35	265	5	-	620	-	1.65
16	650	15	18	6	55	55	Development	-	-	-	-	-	-	1.44
17	475	15	18	6	55	55	Development	-	-	-	-	-	-	1.87
18	625	15	18	6	55	55	Development	-	-	-	-	-	-	1.42
19	725	15	18	6	55	55	Development	-	-	-	-	-	-	1.33
20	780	15	18	6	55	55	Development	-	-	-	-	-	-	1.26

Table 2: ACPS Input Parameters and Results for the Alternative Pillar Layout at New Elk

` Scenario	High Average Depth of Cover (ft)	Number of Entries	Width Entry (ft)	Height Mining (ft)	Width Pillar (ft)	Length Pillar (ft)	Conditions Stress	CMRR	Interburden Thickness (ft)	Seam Thickness (ft)	Remnant Pillar Width (ft)	Gob Width 1 (ft)	Gob Width 2 (ft)	ACPS SF
10A	540	15	18	6	55	120	Remnant Pillar	35	260	5	185	620	620	1.99
11A	600	15	18	6	55	95	Gob-Solid	35	260	5	-	620	-	2.00
12A	760	15	18	6	55	80	Development	-	-	-	-	-	-	1.99
15A	425	15	18	6	55	70	Gob-Solid	35	265	5	-	620	-	1.99
16A	650	15	18	6	55	85	Development	-	-	-	-	-	-	2.03
17A	475	15	18	6	55	60	Development	-	-	-	-	-	-	2.05
18A	625	15	18	6	55	85	Development	-	-	-	-	-	-	2.01
19A	725	15	18	6	55	95	Development	-	-	-	-	-	-	1.99
20A	780	15	18	6	55	110	Development	-	-	-	-	-	-	2.01
4A	675	15	18	6	55	110	Remnant Pillar	35	255	5	185	620	620	1.97
5A	675	15	18	6	55	110	Gob-Solid	35	260	5	-	620	-	2.02
7A	475	15	18	6	55	85	Remnant Pillar	35	260	5	185	620	620	2.01
8A	550	15	18	6	55	80	Gob-Solid	35	265	5	-	620	-	2.01
9A	450	15	18	6	55	60	Gob-Solid	35	260	5	-	620	-	1.99

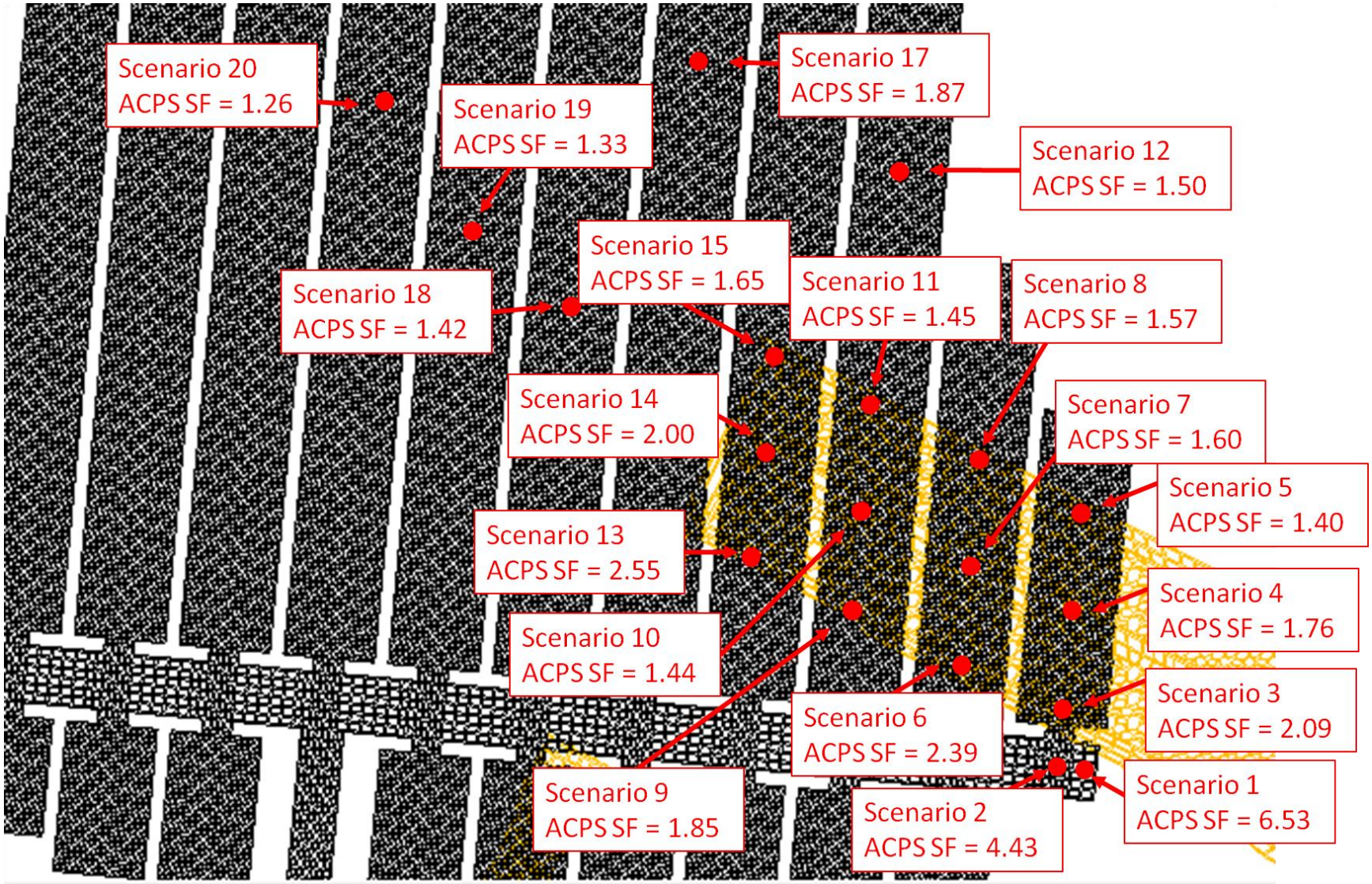

Figure 1: ACPS Safety Factor Results (Scenarios 1-15, 17-20)

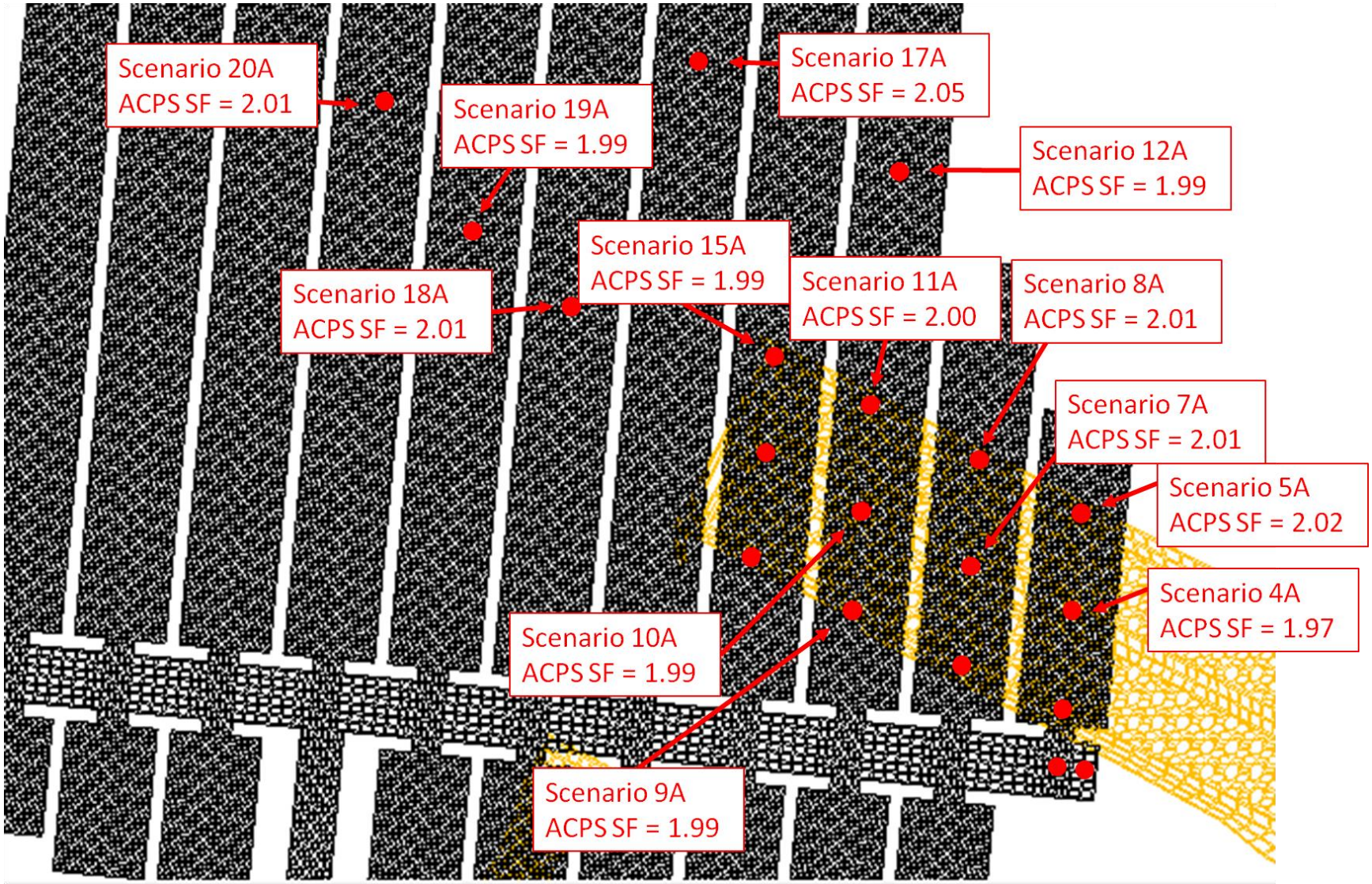

Figure 2: ACPS Safety Factor Results (Scenarios 4A, 5A, 7A-12A, 15A, 17A-20A)