

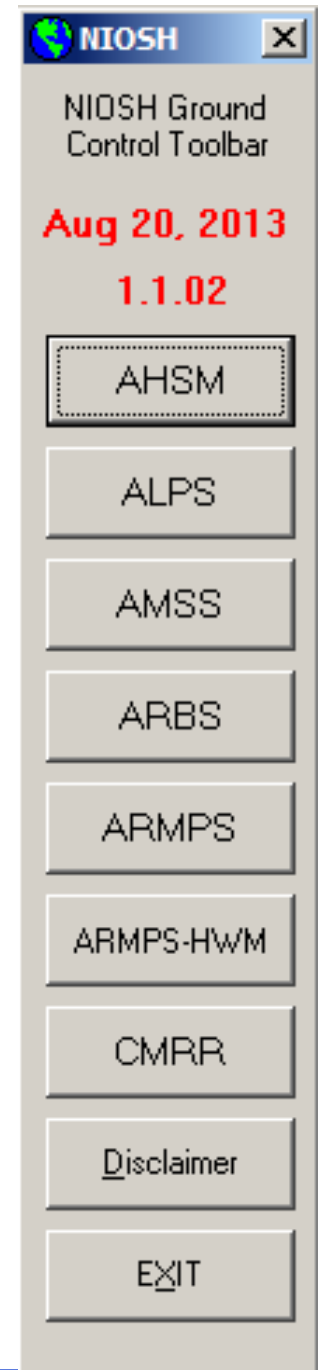
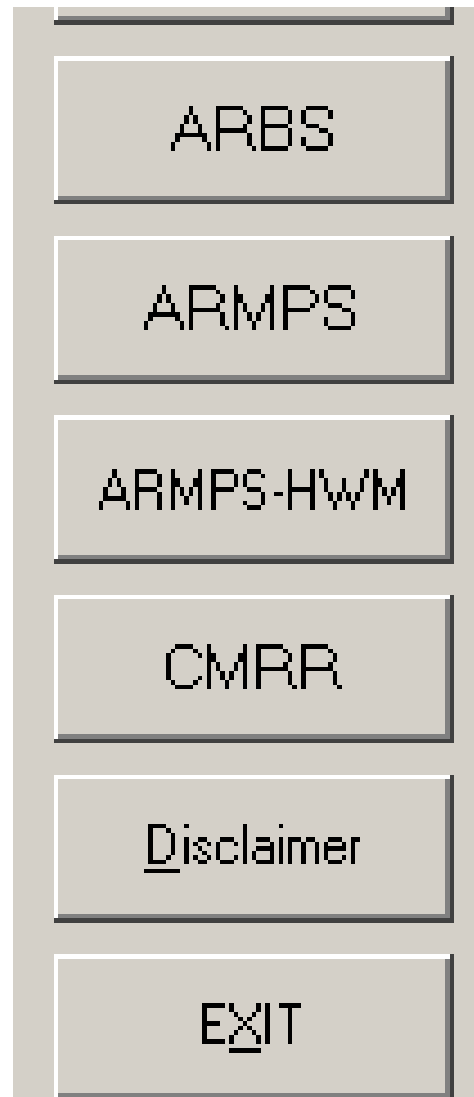
Analysis of Coal Pillar Stability (ACPS): A New Generation of Pillar Design Software

Zach Agioutantis, University of Kentucky, USA

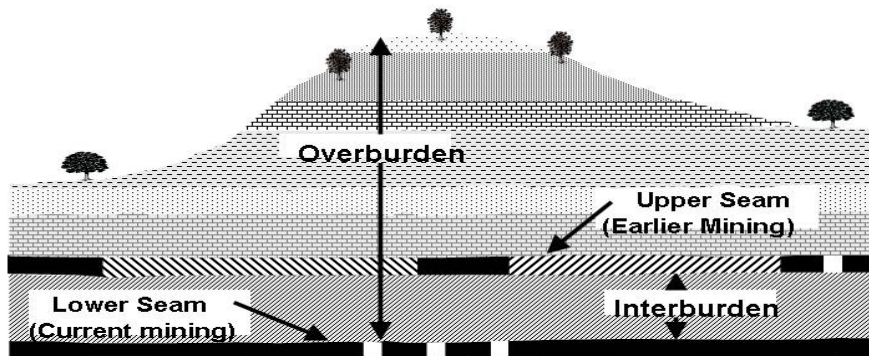
Christopher Mark, MSHA



The NIOSH Ground Control Toolbar



NIOSH Pillar Design Software



ANALYSIS OF MULTIPLE SEAM STABILITY (AMSS)

Z. Agioutantis and C. Mark, PEM, Lexington, KY, Sept 14, 2018





About ARMPS

[Top](#) [Previous](#) [Next](#)

The "Analysis of Retreat Mining Pillar Stability" (ARMPS) program was originally created by Dr. Christopher Mark, Mining Engineer, of the United States Bureau of Mines, Pittsburgh Research Center, (now NIOSH), in MS Basic.

It was later updated to version 4 for the Windows environment. Version 5.x was created by Dr. Zach Agioutantis. ARMPS 2010 (ARMPS version 6) was also created by Dr. Zach Agioutantis.

The help and support of Dr. Chris Mark during all development and debugging stages is greatly appreciated.



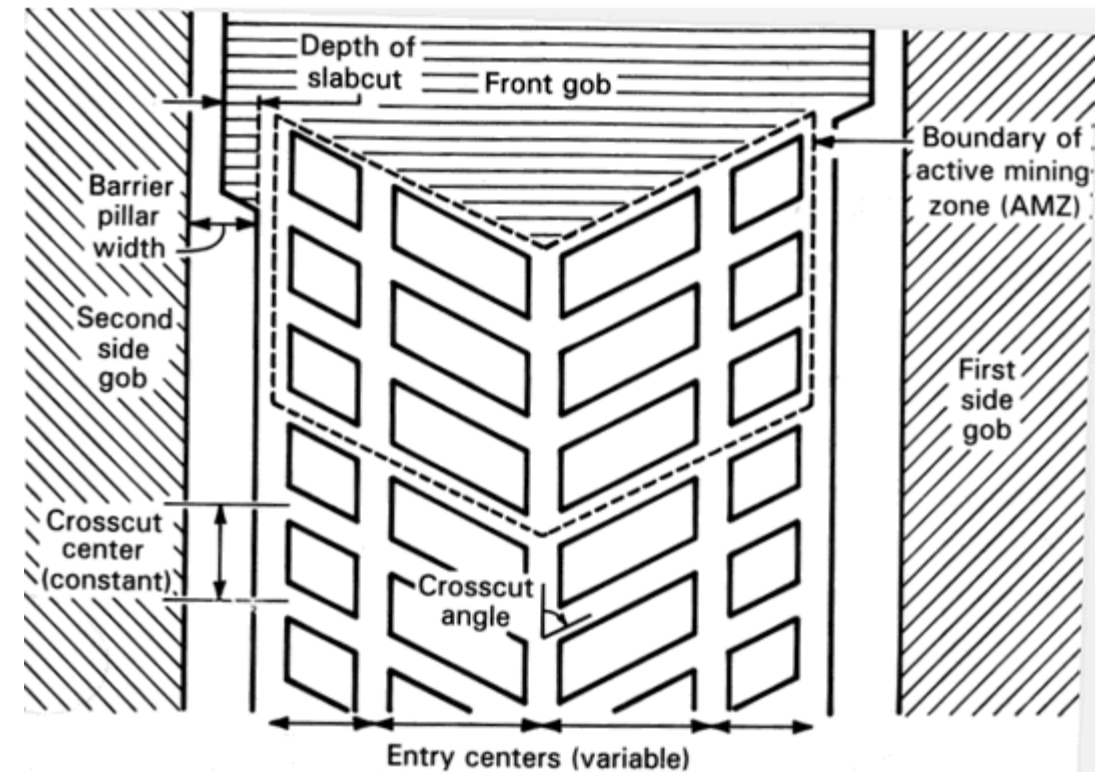
NIOSH Pillar Design Software

- ARMPS is used for any development mining, retreat mining, and most bleeder pillar analyses.
- ALPS is used only for the tailgate corner of longwall panels.
- AMSS is for multiple seam interactions, and it incorporates ARMPS and ALPS evaluations.

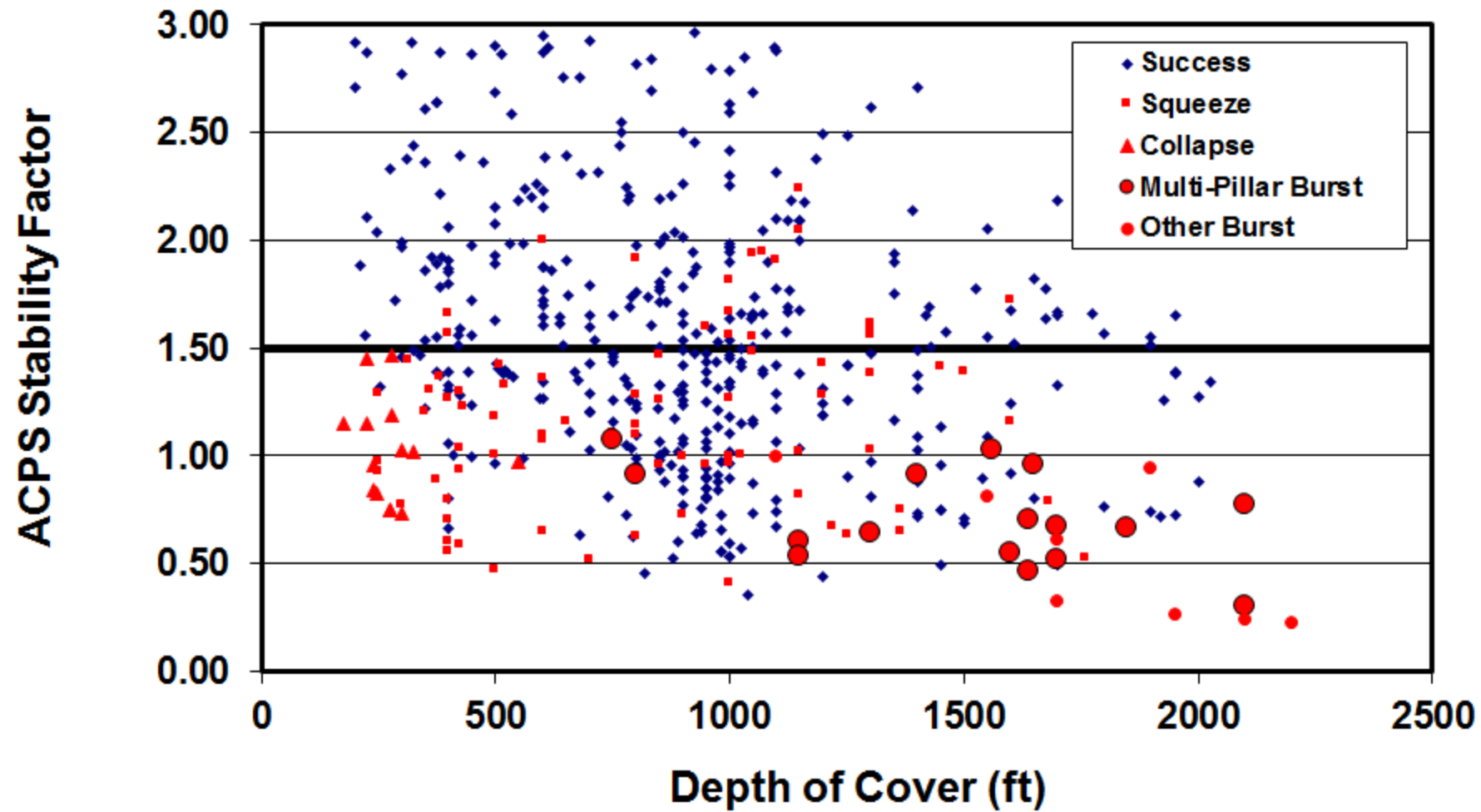


Inconsistencies

- ALPS had an advanced geometry module (variable cross cut angle, variable cross cut spacing per pillar row)
- ARMPS did not have an advanced geometry module (only allowed for uniform cross cut angle)
- AMSS used the same logic when implementing these algorithms.



Empirical Criteria

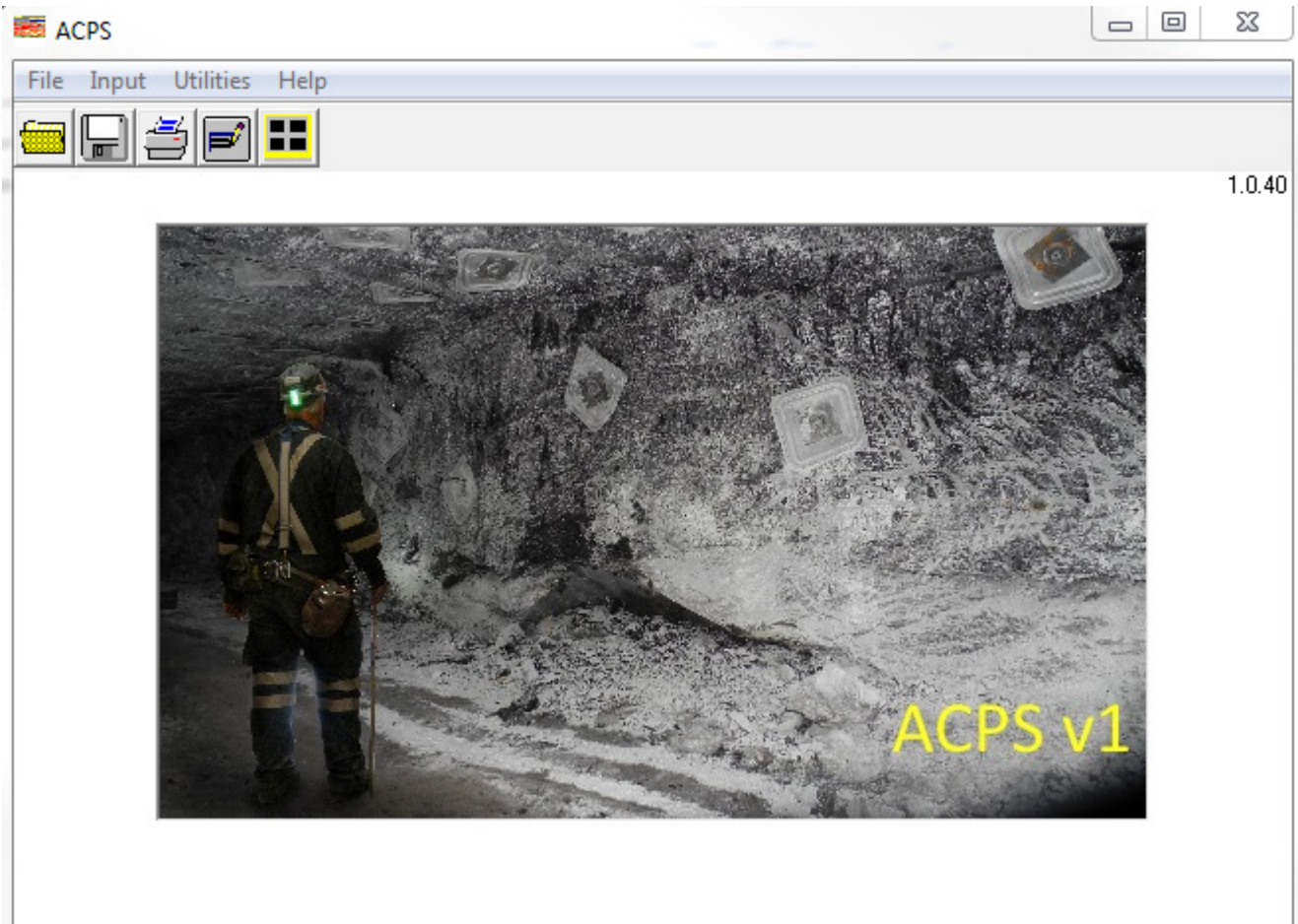


The case history data bases are the heart of these methods.

Z. Agioutantis and C. Mark, PEM, Lexington, KY, Sept 14, 2018



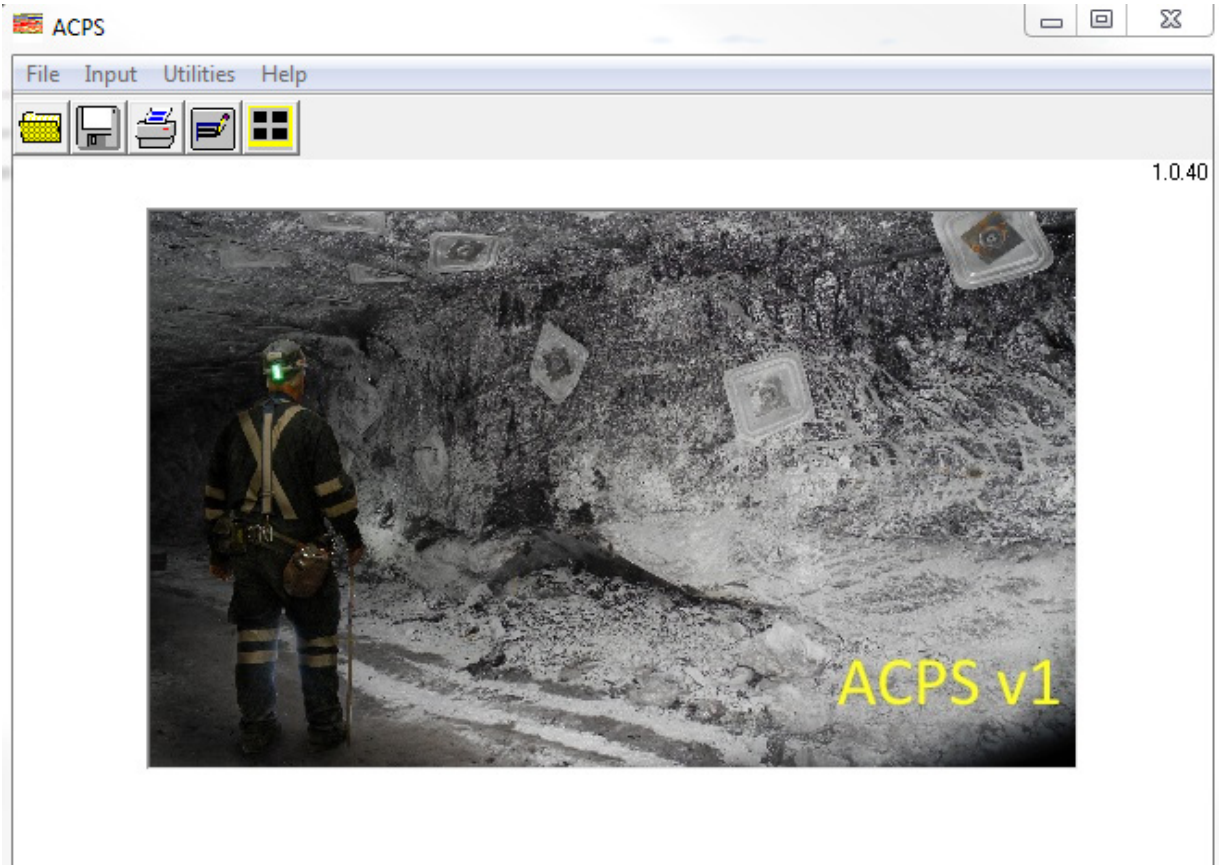
Goals for ACPS



- Simplify pillar design process
- Consistent and uniform results
- Improved and updated methods



New Features in ACPS



- “Advanced Geometry” for complex mining layouts
- More flexibility with “Leave Pillars” for retreat mining
- New multiple seam guidelines using expanded data base
- New CMRR “Estimator”
- New Help file



ACPS Program Flow

Project Description

Title and description

Title

Project Type

Development / Room-and-Pillar

Longwall Gate

Set As Default

Current units

feet, lbs

meters, kN

Help OK

Cancel Next Form

- Choose project type
- Choose project units
- Additional options within each project type



Familiar Input Form

Input Tailgate Pillar Development Parameters

Development Defaults Longwall Retreat Multiple Seam

Panel specification

Entry height (ft) 5

Depth of cover (ft) 1000

Crosscut angle (deg) 90

Entry width (ft) 20

Crosscut spacing (ft) 100
(center-to-center)

Number of entries 4

Advanced Geometry

Multiple Seam

Average extraction ratio (%) 52.0

Center-to-center entry spacing

P1 P2 P3

100 100 100

Equal spacing

Advanced geometry data

Crosscut spacing

50 50 50

Crosscut angle

90 90 90

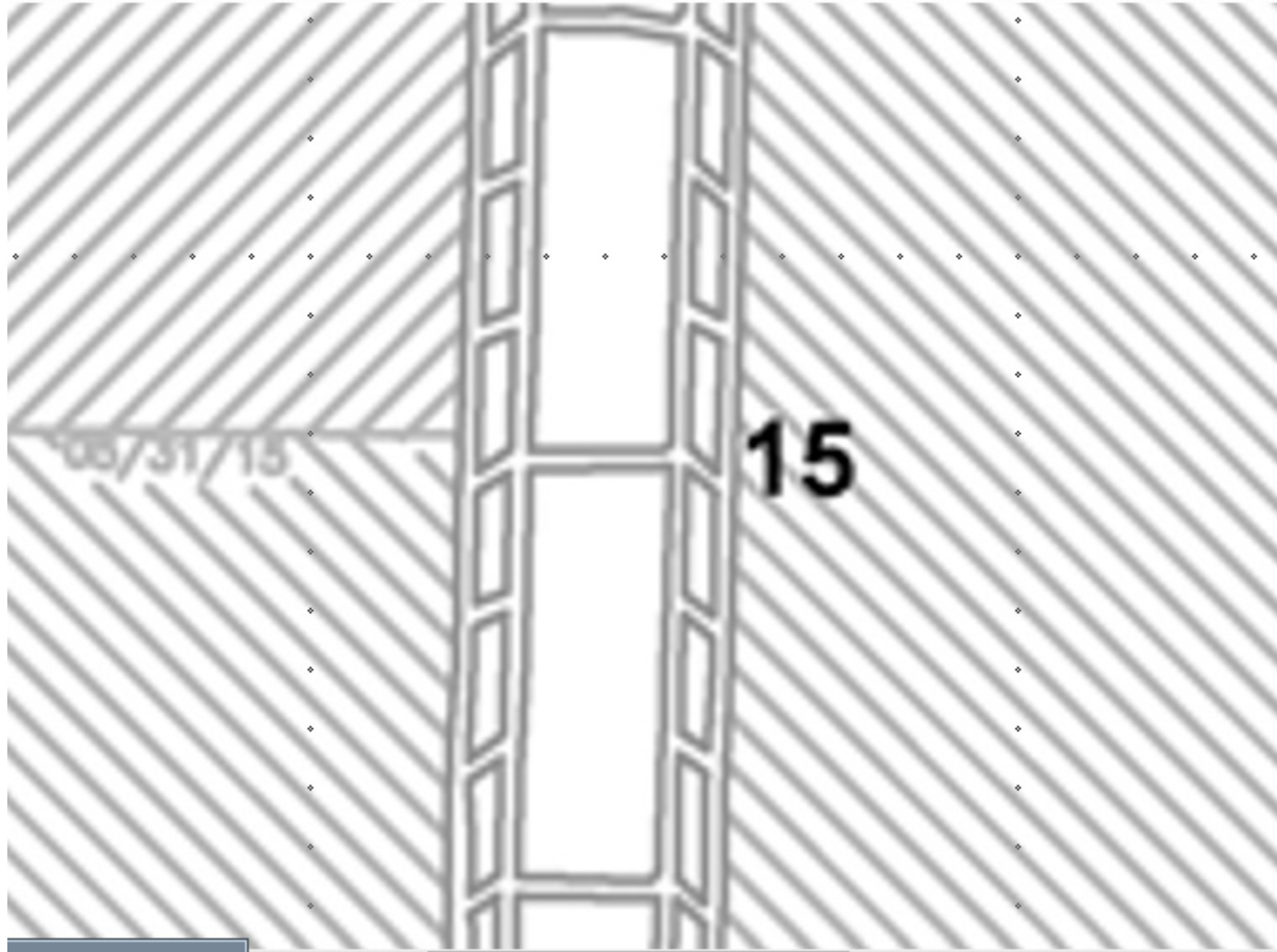
Equal crosscuts

Equal angles

Previous Form Copy Clip Results View Plan Help Cancel OK



Variable Center-to-Center, Xcut Angle, Xcut Spacing



Development

Defaults

Longwall Retreat

Multiple Seam

Only for Development

Panel Widths and Abutment Angles

First panel width (ft)

Abutment angle for first panel

Second panel width (ft)

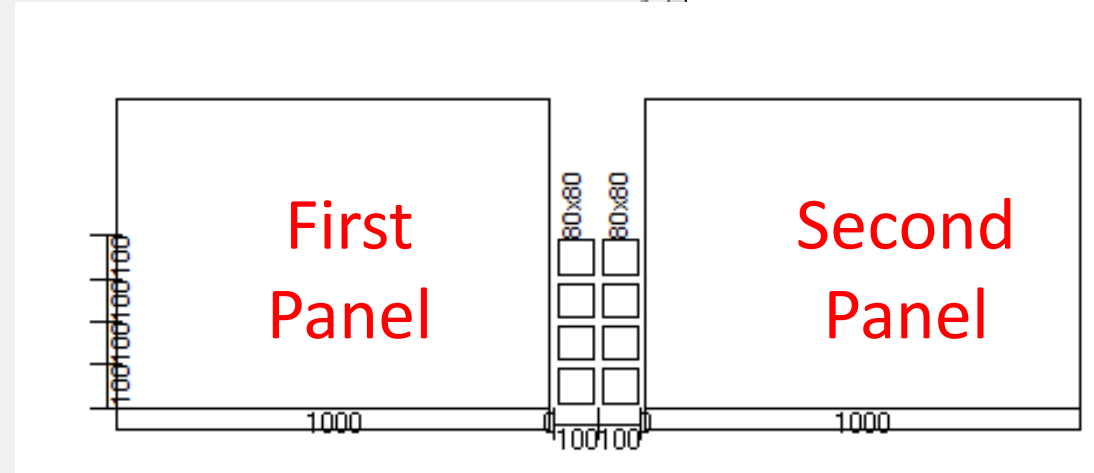
Abutment angle for second panel

CMRR

CMRR

Suggested Tailgate SF based on CMRR

CMRR Estimator



Previous Form

Copy Clip

Results

View Plan

Help

Cancel

OK



Project Description



Title and description

Title

Project Type

- Development / Room-and-Pillar
- Longwall Gate

Set As Default

Current units

- feet, lbs
- meters, kN

Help

OK

Cancel

Next Form



Development

Defaults

Retreat

Multiple Seam

Panel specification

Entry height (ft)

Depth of cover (ft)

Crosscut angle (deg)

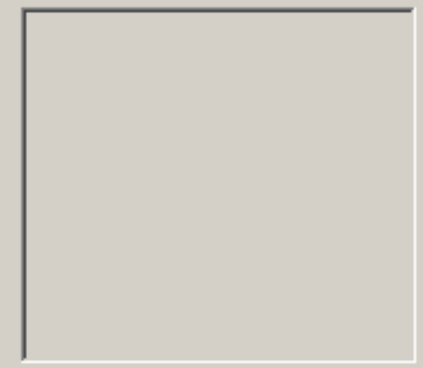
Entry width (ft)

Crosscut spacing (ft)
(center-to-center)

Number of entries

- Advanced Geometry
- Retreat Mining
- Multiple Seam

Average extraction ratio (%)



Center-to-center entry spacing

P1	P2	P3	P4	P5
<input type="text" value="70"/>	<input type="text" value="70"/>	<input type="text" value="70"/>	<input type="text" value="70"/>	<input type="text" value="70"/>

Equal spacing



Advanced Geometry Options

Input Development / Room-and-Pillar

Development Defaults Retreat Multiple Seam

Panel specification

Entry height (ft) 6 Number of entries 6

Depth of cover (ft) 1000

Crosscut angle (deg) 90

Entry width (ft) 20

Crosscut spacing (ft) (center-to-center) 90

Advanced Geometry

Retreat Mining

Multiple Seam

Average extraction ratio (%) 45.4

Center-to-center entry spacing

P1 P2 P3 P4 P5

70 70 70 70 70

Advanced geometry data

Crosscut spacing

90 90 90 90 90

Crosscut angle

60 90 90 90 60

Prev Form Copy Clip Results View Plan Help

View Plan

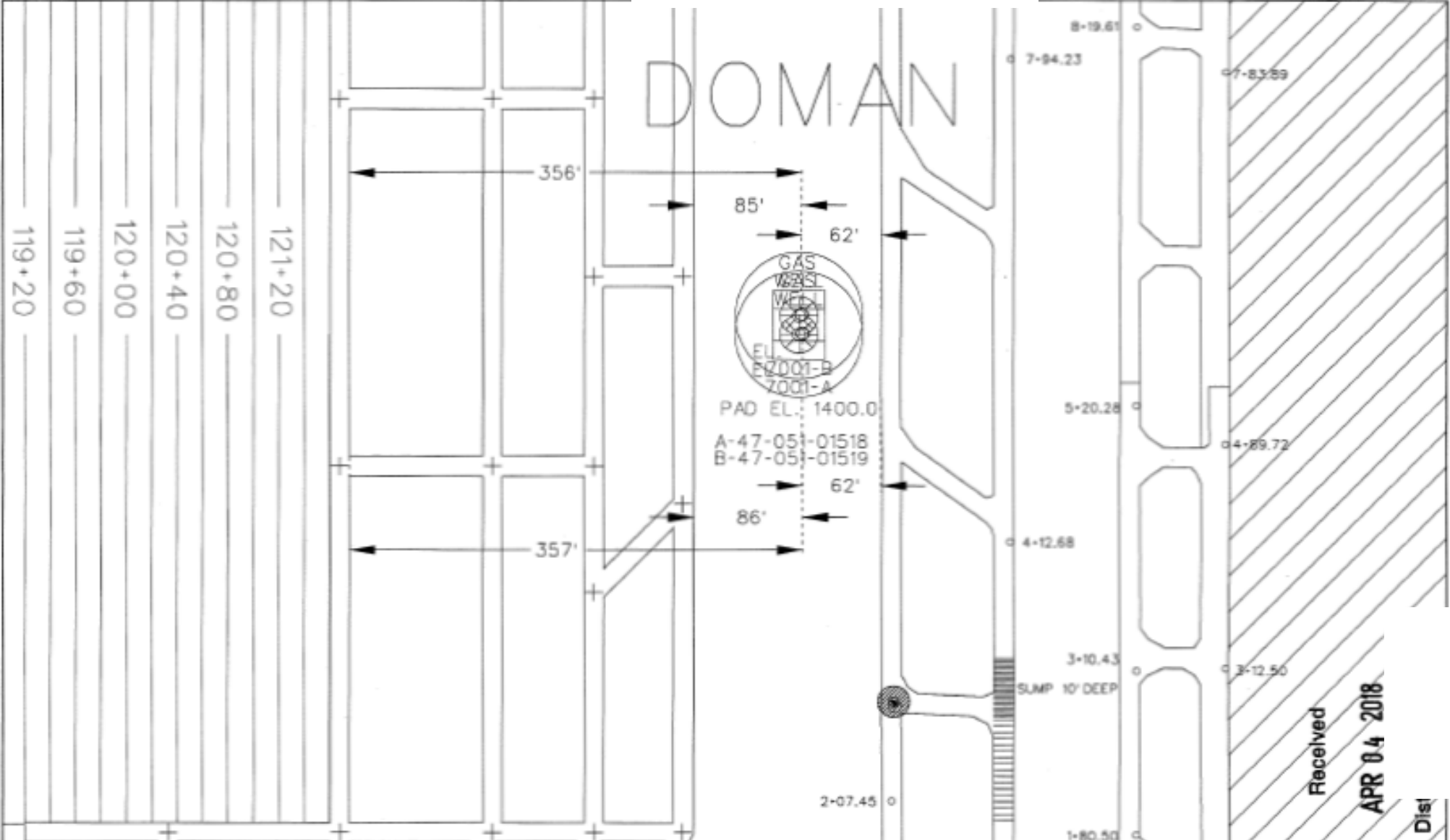
File Edit Settings

ACPS: Actual Pillar Dimensions (width*length, ft). Entries shown from left to right.

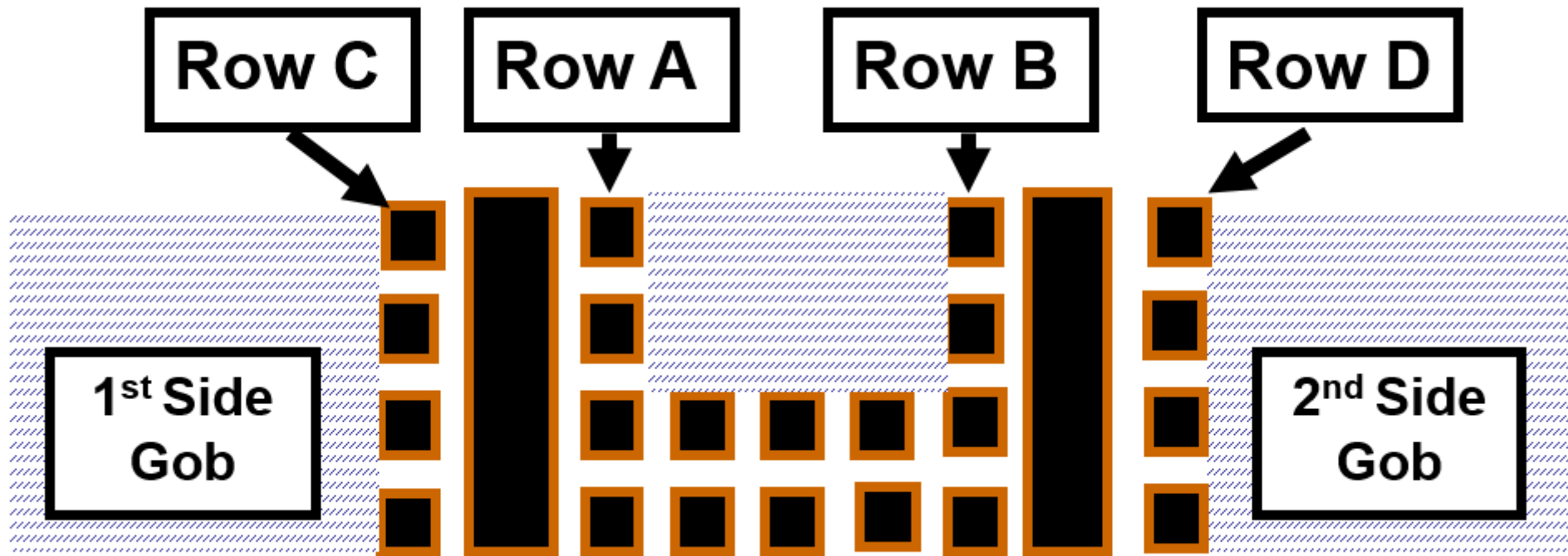
500 100 600 70 90 90 90 90 70 70 70 50x67 50x70 50x70 50x70 50x67



Modeling Complex Geometries is Easy



ARMPS 2010 “Leave Pillar” Options



ACPS “Leave Pillar” Options During Retreat Mining

Input Development and Pillar Recovery Parameters

Development Defaults Retreat Multiple Seam

Loading Condition

- Development load (no nearby gob)
- One active retreat section
- One active section & one side gob
- One active section & two side gobs

Active Gob Parameters

Extent of active gob (ft)

Abutment angle for active gob (deg)

First Side Gob Parameters

Extent of first side gob (ft)

Abutment angle for first side gob (deg)

Barrier pillar width for first side gob (ft)

Depth of slab cut in barrier pillar (ft)

Bleeder Pillars

Row A

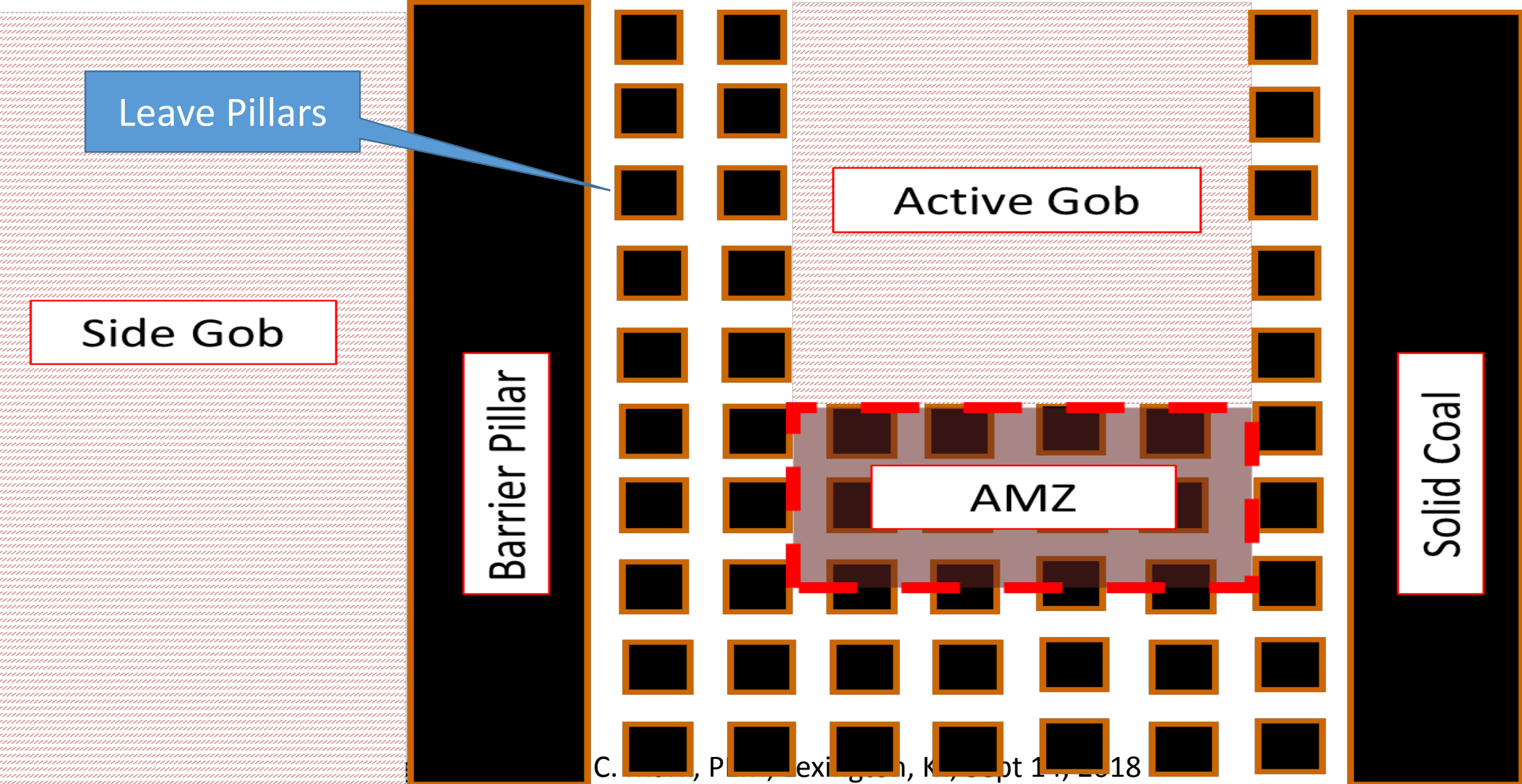
Pillars left in the Panel

<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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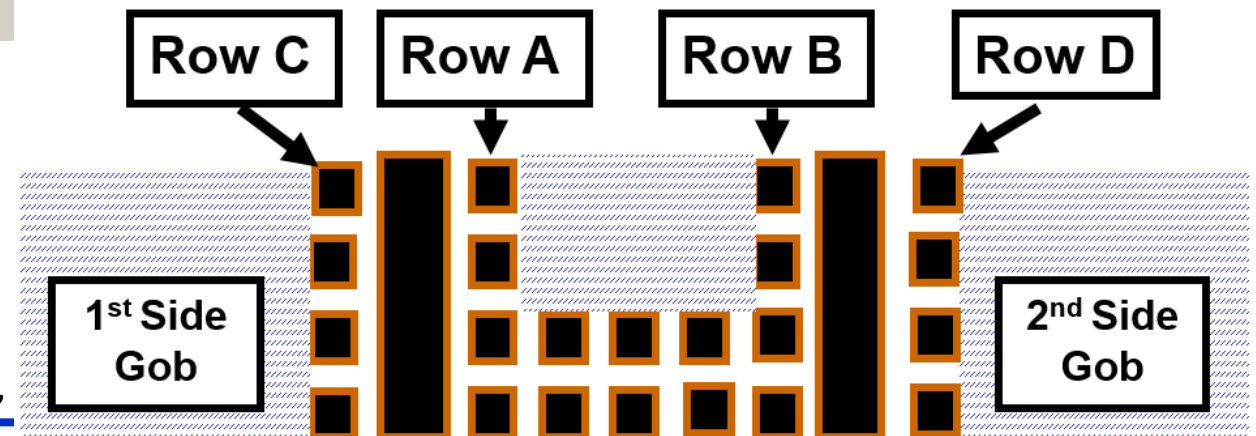
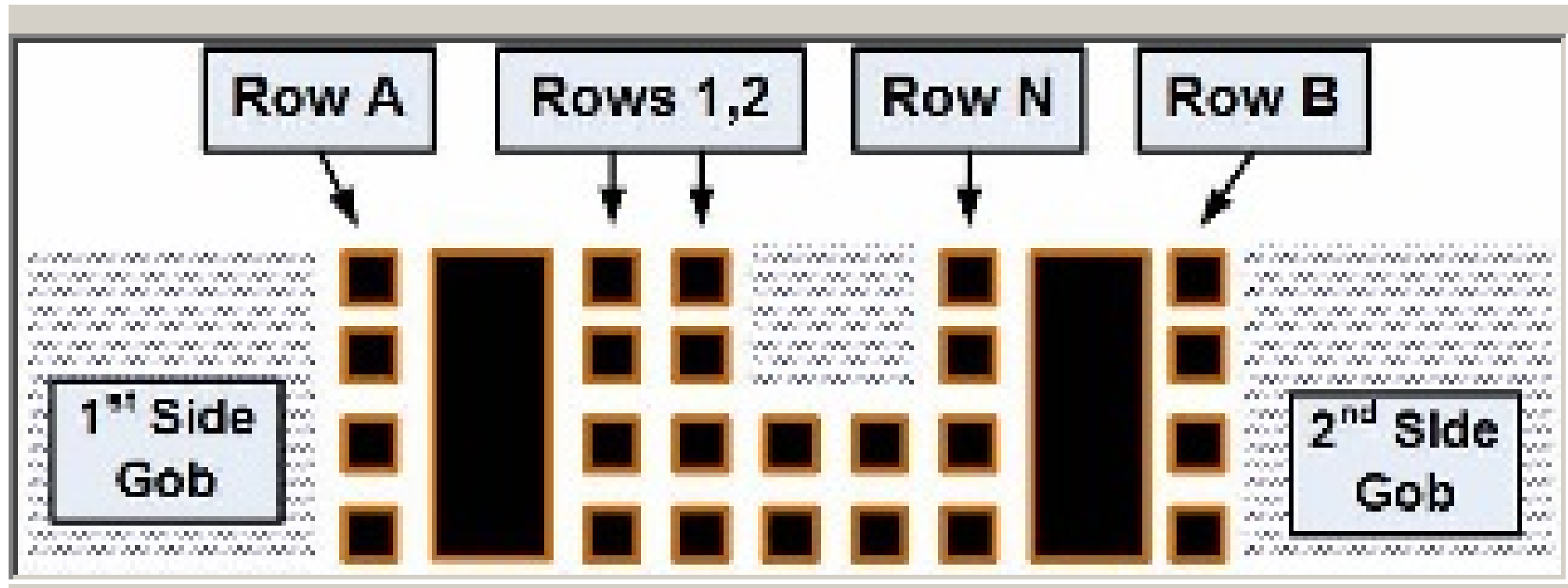
Prev Form Copy Clip Results View Plan Help Cancel OK



“Leave Pillar” Options for ACPS



Comparison “Leave Pillar” Options: ACPS vs ARMPS 2010



Z. Agioutantis and C. Mark,



Original Multiple Seam Module (AMSS)

Geometry and Previous Seam Parameters

Active seam mining

Longwall mining

Room and Pillar mining (development and retreat)

CMRR

Remnant structure in previous seam

Gob Solid Layout

Remnant Pillar

Vertical position

Active OVER previous

Active UNDER previous

Input parameters for previous seam mining

Interburden Thickness (ft)

Seam Thickness (ft)

Width of Gob (ft)

Width of Remnant (ft)

Width of Gob 1 (ft)

Width of Gob 2 (ft)

~~Age of the Undercut Markings (ft)~~

Plan View

Cross Section View

Large View

Copy Dialog Image to Clipboard Help Cancel OK Next Form



Updated Multiple Seam Analysis

Input Development and Pillar Recovery Parameters

Development Defaults Retreat **Multiple Seam**

Active seam mining

CMRR Estimator CMRR 50

Remnant structure in previous seam

Gob Solid Layout

Remnant Pillar

Multiple Seam

Active OVER previous

Active UNDER previous

Input parameters for previous seam mining

Interburden Thickness 120

Seam Thickness 5

Width of Gob 1000

Width of Remnant 70

Width of Gob 1 260

Width of Gob 2 380

Plan View

Previous Mine

Active Mine

Entry Width

Pillar Length

Pillar Width

Gob

Gob Width

Cross Section View

Active Mine

Previous Mine

Interburden

Seam Height

Large View

Prev Form Copy Clip Results View Plan Help Cancel OK

- Statistics were updated
- The Multiple Seam option is now on the same form as a the rest of the input data.

CMRR Estimator

Input Development and Pillar Recovery Parameters

Development Defaults Retreat Multiple Seam

Active seam mining

CMRR Estimator CMRR 50

Remnant structure in previous seam

Gob Solid Layout

Remnant Pillar

Vertical position

Active OVER previous

Active UNDER previous

Input parameters for previous seam mining

Interburden Thickness 120

Seam Thickness 5

Width of Gob 1000

Width of Remnant 70

Width of Gob 1 260

Width of Gob 2 380

Plan View

Cross Section View

Large View

Prev Form Copy Clip Results View Plan Help Cancel OK



Coalfield Location

- Northern Appalachia
- Central Appalachia
- Southern Appalachia
- Illinois Basin
- Utah
- Other Western

45

1	Thick Claystone	40
2	Thick Shale	45
3	Stackrock (laminated sandstone/shale)	45
4	Siltstone	50
5	Bedded Sandstone	55
6	Massive Sandstone	55
7	Unknown	45

< >

Help

Cancel

OK

CMRR Estimates for CENTRAL APPALACHIAN COALFIELDS

Dominant Rock Type in Primary Bolt Horizon

CMRR

Thick Claystone	40
Thick shale	45
Stackrock (laminated sandstone/shale)	45
Siltstone	50
Bedded Sandstone	55
Massive Sandstone	65

Roof rock type must be validated with known geologic data. If data is unavailable, then a conservative CMRR = 45 should be assigned.

ACPS Help

Hide Back Forward Home Print Options

Contents Index Search

Type in the keyword to find:

ACPS VERSION 1.0
USER'S GUIDE TO ANALYSIS
OF COAL PILLAR STABILITY

[Top](#)
[Next](#)

[Overview](#)

[The File Menu](#)

[The Edit Menu](#)

[The Calculation Menu](#)

[The Utilities Menu](#)

[The Help Menu](#)

[References](#)

[About ACPS](#)

*Help File Updated: Tuesday,
 September 11, 2018*

Display

[About ACPS](#)
 Abutment Angle
 Abutment Load
 Abutment Load Distribution
 ACPS
 ACPS Development
 ACPS Loads
 ACPS Options
 ACPS Overview
 ACPS Stability Factor
 ACPS Stability Factors
 ACPS.INI
 Active Gob
 Active Mining Method
 Active Mining Zone
 Active Over Previous Mining
 Active Panel
 Active Under Previous Mining
 Advanced Geometry
 Agioutantis, Zach
 Alternative Criteria
 AMZ
 AMZ Breadth
 AMZ Load Bearing Capacity
 AMZ Loadings
 AMZ Loads
 Barrier Pillar Loads
 Barrier Pillar Stress
 Barrier Pillar Width
 Barrier Pillars
 Bleeder Pillars
 Browsing Text Files
 Calculations and Graphs
 Case History


- Context Sensitive Help
- PDF Help File

2 Analysis of Coal Pillar Stability Manual

Table of Contents

Foreword	0
Part I ACPS Overview	6
1 Overview	7
2 Structure of ACPS	8
3 ACPS Calculations Overview	9
4 Origins of ACPS	10
Part II The File Menu	13
1 Creating New Files	14
2 Opening Existing Files	14
3 Saving Files	16
4 Saving Files under Different Names (Save As)	16
5 Setting Up the Printer	18
6 Import ARMP's Project	18
7 Import ALPS Project	18
8 Import AMSS Project	17
9 Printing Files	17
10 Print Preview	18
11 Browsing Text Files	18
12 Exiting the Program	18
Part III Input Parameters	20
1 Project Description	21
2 Development / Room-and-Pillar	22
Input Parameters: Development	22
Input Parameters: Defaults	25
Input Parameters: Retreat	25
Input Parameters: Multiple Seam	27
3 Longwall Tailgate	28
Input Parameters: Development	28
Input Parameters: Defaults	30
Input Parameters: Longwall Retreat	31
Input Parameters: Multiple Seam	32
Part IV CMRR Estimator	34
Part V Interpretation of ACPS Stability Factors	36
1 Types of Ground Control Failure	37
2 Stability Factor for the Development/Room and Pillar Module	37

Analysis of Coal Pillar Stability Manual



Tuesday, September 11, 2018

Conclusions

- Integrated approach covering all pillar design formulations
- Updated multiple seam analysis
- Familiar interface
- Free software for the international mining community
- Ability to import data directly from ARMPS, ALPS and AMSS files
- New comprehensive help file



Current Status and Outlook

- ACPS is currently in version 1.0.49 and ... its almost done
- MSHA tech support personnel have already been trained on ACPS (April 2018)
- ACPS was also shared with industry during the ground control meeting in Morgantown in July 2018
- MSHA is currently accepting roof control plans with ACPS
- ACPS is almost ready for wide distribution – a few minor bug fixes remain



Website for downloading the program

- <http://www.minegroundcontrol.com/ground-control/>

Mine Ground Control

Home of Software for the Mining and Geotechnical Community

